moray offshore renewables ltd

Environmental Statement

Technical Appendix 7.3 A - Marine Mammals Environmental Impact Assessment

Telford, Stevenson, MacColl Wind Farms and associated Transmission Infrastructure Environmental Statement

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APPENDIX 7.3 A

This document was produced by Natural Power on behalf of Moray Offshore Renewables Ltd

Document Owner	**Dr Sarah Canning, Natural Power**
Document Status	**Final**
File Name	**401_003_R_NPC_MORL_MF35**

Revision	Date	Description	Originated By	Checked By	Approved By
A1	Nov 2011	For review	SJC	NM	NM
A2	April 2012	For review	SJC	CJP	NM
A3	May 2012	Final draft	SJC	GH/PT	NM
A4	June 2012	Final	SJC	GH/PT	NM

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Contents

1. Introduction

The aim of this assessment is to describe the significance of effect that specific activities associated with an offshore wind farm development may have on marine mammal populations within the proposed development sites (Telford, Stevenson and MacColl) and associated offshore transmission infrastructure (OfTI) and across the Moray Firth as a whole.

The assessment is divided into sections for ease of reference. Section 2 provides the Project Parameters that have been used to inform the impact assessment undertaken for marine mammals, and Section 3 the assessment methodologies used.

Sections 4, 5 and 6 provide the predicted impacts from the construction, operation and decommissioning of the Project respectively. For the construction phase impacts, the primary assessment presented examines the potential effects of all three proposed sites (Telford, Stevenson and MacColl) in combination. This assessment includes consideration of a two, three and five year build out scenario for the combined projects. A secondary, sensitivity assessment has been performed examining the potential impacts from the three proposed developments (Telford, Stevenson and MacColl) independently to each other. In addition to the generating station elements of the Project, these sections also include consideration of the Offshore Transmission Infrastructure (OfTI) to connect the wind farms to landfall at Fraserburgh, and an additional met mast within the footprint of the three proposed sites.

A cumulative impact assessment of projects identified within and outwith the Moray Firth is as Section 7. The projects included within this assessment are:

Developments within the Moray Firth:

- Beatrice Offshore Wind Farm (the BOWL project)
- SHETL hub and transmission cable.
- Port and harbour developments within the Moray Firth; and
- Oil and gas activities.

Developments outwith the Moray Firth:

- Proposed Forth and Tay offshore wind projects (Neart na Gaoithe, Firth of Forth and Inch Cape offshore wind farms) ;
- Proposed European Offshore Wind Deployment Centre (EOWDC); and
- Proposed Pentland Firth and Orkney wave and tidal energy developments.

Finally, current best practice management and mitigation measures are outlined within Section 8.

Key impacts to be reviewed are summarised in Table 1.1 below.

Table 1.1: Summary of the key risks for marine mammals addressed in this assessment, and their associated activities.

Risk	Associated Activity	Potential Effect
Permanent hearing damage	Increased noise levels, in particular from piling.	Reduction in ability to find prey, avoid predators and socially interact.
Temporary Disturbance/ Displacement	Increase vessel movement; Elevated construction noise;	Restricted access to food sources, breeding grounds or migration routes leading to reduced fitness.
Collision	Vessel movement, including those with ducted propellers.	Physical injury and reduced viability.
Long-term avoidance	Foundation footprints, increased Operation and Maintenance related vessel movement.	Habitat disturbance leading to reduction in prey source; Restricted access to food sources, breeding grounds or migration routes leading to reduced fitness.
Reduction in prey	Secondary effect resulting from increased noise and/or vibration (including electromagnetic fields), habitat disturbance or habitat loss due to the physical presence of the turbines.	Reduction in fitness.
Stranding	Electromagnetic fields from operational cables.	Disruption of navigation mechanism, possibly resulting in stranding (and death).
Toxic/Non-toxic contamination	General construction activities leading to increased sediment; sacrificial anodes and antifouling paints.	Habitat disturbance leading to reduction in foraging ability and prey resources leading to reduced fitness. Contamination of food chain leading to reduced fitness.

A review of marine mammal species that utilise the Moray Firth can be found in ES Chapter 4.4: Marine Mammals, and the associated Technical Appendix 4.4 A: Baseline marine mammals.

All marine mammal species that may be encountered in the vicinity of the proposed sites are considered target species and of high sensitivity due to the fact that all cetaceans are listed on Annex IV of the Habitats Directive and bottlenose dolphins, harbour porpoises, harbour seals and grey seals are listed on Annex II.

This assessment will concentrate on the key species highlighted in ES Chapter 4.4 and assume that conclusions drawn can also be applied to less frequently observed species. The key species to be assessed are:

- Grey seal;
- Harbour seal;
- Harbour porpoise;
- Bottlenose dolphin; and
- Minke whale.

2. Project parameters

Key components of the Project design relevant for impact assessment for marine mammals are:

- Duration and timing of construction activities;
- Associated vessel activity;
- Number of (and type of) offshore structures (wind turbines, OSP's, met mast); and
- Extent of array and layout.

This assessment has focussed on key activities within the MORL Rochdale Envelope that may have an impact on marine mammal species during the life cycle of the development. The parameters from the Rochdale Envelope used in this assessment are described in Table 2.1 below. The rationale for pile diameter and soil province chosen for the noise impact modelling is provided in ES Chapter 3.6: Underwater Noise.

Table 2.1: MORL Rochdale Envelope Parameters Considered in the Assessment

Potential Effect	**Rochdale Envelope Scenario Assessed**
Construction & Decommissioning	
Permanent threshold shift (PTS – hearing damage)	Greatest potential cause of auditory damage will be from piling noise during construction. Worst case (as modelled): • Wind farms: 1356 x 2.5 m diameter pin piles over five, three or two year construction phases. Based on 339 turbines, four piles per turbine. • Met mast: single mast with monopole foundation of 4.5 m diameter. • OfTI: worst case is 128 x 3 m piles from eight substations (16 piles per OSP for jack-up foundation type)
Disturbance/ displacement	Greatest potential cause of disturbance/displacement will be from increased noise, in particular from piling, created during construction. The parameters assessed are associated with worst case scenario (as modelled): • Wind farms: 1356 x 2.5 m diameter pin piles over five, three or two year construction phases. Based on 339 turbines, four piles per turbine. • Met mast: single mast with monopole foundation of 4.5 m diameter. • OfTI: 128 x 3m piles over up to six years of construction activity. Increased vessel movement based on predicted number of transects between construction sites and onshore construction port.
Collision risk	An assessment has been undertaken based on predicted increases in vessel movements within and around the site, taking account of the presence of standard vessel routes which will localise effects. A separate study on ducted propeller related injury from vessel movement near haul-out sites has been undertaken as part of the impact assessment described below. Cognisance has been taken of consultation responses by Marine Scotland to the (consented) MORL met mast application.
Reduction in prey sources	Secondary effects as a result of changes in prey distribution or density. Worst case likely to be gravity base foundations (maximum 339 turbines plus one met mast, sea bed take of 65mx65m) and associated loss of habitat. The effects of piling noise on prey viability are also considered.
Reduction in foraging ability	Secondary effect due to increased suspended sediment associated with construction activities.

Operation	
Collision risk from maintenance vessels	An assessment has been undertaken based on predicted increases in vessel movements within and around the site during operation. A separate study on ducted propeller related injury from vessel movement near haul-out sites has been undertaken. Cognisance has been taken of consultation responses by Marine Scotland to the (consented) MORL met mast application.
Barrier to movement / displacement	Physical barrier: worst case, minimum spacing between turbines for sites 1, 2 and 3 (840 x 600 m). Displacement potentially caused by operational turbine noise. Assessment has been based on published noise levels (i.e Thomsen *et al*., 2006). Worst case scenario, 7 MW turbines.
Electromagnetic fields	33-66 kV AC cable for inter-array cables; 220 kV AC cable for inter-platform cables; 320 kV DC cable for export.
Long-term reduction in prey availability	Secondary effects due to changes in prey distribution or density as a result of loss of habitat or avoidance of operational noise.
Toxic contamination	Sacrificial anodes & anti-fouling coatings

Temporary Threshold Shift (TTS) has not been considered within this impact assessment. It is considered a short term change in the sensitivity of hearing due to exposure to excessive noise. For example, studies of TTS in bottlenose dolphins showed that for TTS of about 3–4 dB (exposure SELs of 195-199 dB re 1 Pa^2 s), recovery was nearly complete (i.e., TTS was no longer measurable) by 10 minutes post-exposure (Finneran et al., 2005). For exposure SELs of 201 and 203 dB re 1 Pa^2 s, TTS was larger (4–5 dB) and full recovery was not complete by 10 min (Finneran et al., 2005). However, in all cases, recovery to within the normal range of pre-exposure thresholds was complete by the following day (when the dolphins were re-tested). As individuals experiencing TTS demonstrate full recovery of their hearing abilities it is generally assumed to be innocuous (Mooney et al., 2009). Given these relatively short term effects, and given the highly precautionary assumptions we make with regard to the biological effects of PTS and behavioural responses (see Table 4.7 below), MORL did not consider TTS in assessment.

3. Impact Assessment Methodology

The assessment process used for marine mammals is based on methodologies recommended by the Institute of Ecology and Environmental Management (IEEM, 2010). Some additional definitions are provided by Wilhelmsson *et al*., 2010 in a review of potential impacts of offshore wind developments. The basic assessment steps are as follows:

- Identification of potential receptors and description of baseline conditions;
- Description of activities during the different stages of the development predicted to result in potential impacts;
- Characterisation of potential impacts including likelihood of occurrence;
- Assessment of whether impacts are likely to be ecologically significant and the geographical scale at which they may occur;
- Proposal of mitigation measures if applicable;
- Assessment of whether residual impacts (after mitigation) are ecologically significant; and
- Assessment of cumulative impacts.

A list of defining terms used in this assessment can be found in Table 3.1.

An *ecologically significant impact* (in the context of EIA regulations) is defined as an impact that has an effect on the integrity of a site or ecosystem. The geographical scale at which the ecological significance of a potential impact may occur is defined as:

- Local: receptors of local importance;
- Regional: receptors of regional importance;
- National: receptors are a feature of a UK designated site i.e. Site of Special Scientific Interest (SSSI), UK Biodiversity Action Plan (UKBAP) species[1];
- International: receptors are a feature of European designated sites i.e. Special Area of Conservation (SAC).

Certainties in predictions for this assessment follow the criteria described in Table 3.2, based on IEEM guidance (IEEM 2010).

Given the level of legal protection afforded all of the marine mammals likely to be encountered within the Moray Firth, all species of marine mammal are considered to be of high sensitivity in this assessment.

[1] MORL are aware that Marine Scotland is leading the Scottish Marine Protected Area Project for Scottish Waters. SNH and JNCC are providing guidance and scientific advice on the selection of Nature Conservation MPAs and development of an ecologically coherent network. No draft MPAs are available for inclusion within this impact assessment at present.

Table 3.1: Definition of terms used within this assessment.

Term	Definition
Magnitude	Size of potential impact e.g. number of individuals predicted to be affected. For the purposes of this impact assessment, low has been termed as <10% of the population considered, medium as between 10-20%, and high as over 20% of the population considered.
Extent	Area over which impact is predicted to occur. For the purpose of this assessment, the extent has been considered to be the Moray Firth.
Duration	Time period over which impact predicted to occur e.g. short-term (occur over days or weeks); medium-term (occur over complete construction phase); long-term (detectable after 25 years).
Reversibility	Is potential impact predicted to be reversed (either though natural processes or mitigation).
Timing	Period of the year that activity would need to occur, to result in potential impact. It has been assumed for this assessment that construction activities occur throughout the year and do not exhibit seasonality.
Frequency	Frequency of activity leading to potential impact.
Risk	Likelihood that the potential impact to occur.

Table 3.2: Criteria used for predicting certainty in predictions during the assessment.

Term	Definition
Certain	Interactions are well understood and documented, i.e. receptor sensitivity investigated in relation to potential impact, data have comprehensive spatial coverage/resolution and predictions relating to effect magnitude modelled and/or quantified. Probability estimated at >95%.
Probable	Interactions are understood using some documented evidence, i.e. receptor sensitivity is derived from sources that consider the likely effects of the potential impact, data have a relatively moderate spatial coverage/resolution, and predictions relating to effect magnitude have been modelled but not validated. Probability estimated at 50-95%.
Uncertain	Interactions are poorly understood and not documented, i.e. predictions relating to effect magnitude have not been modelled and are based on expert interpretation using little or no quantitative data. Probability estimated at <50%.

Table 3.3 illustrates the assignation of magnitude of impact (proportion of population for which the impact assessment is being undertaken) against duration (days, construction phase and a twenty five year period) that has been used within this assessment.

Table 3.3: Criteria used for predicting significance from magnitude of impact and duration.

	Duration		
Magnitude	**Short term (days)**	**Medium term (construction years)**	**Long term (25yrs)**
High (>20%) of population	Major significance (short term)	Major significance (medium term)	Major significance (long term)
Medium (10-20%)	Minor significance (short term)	Moderate significance (medium term)	Moderate significance (long term)
Low (<10%)	Negligible significance	Minor significance (medium term)	Minor significance (long term)

The magnitude scale was determined through consultation with scientific experts, and guided by population size changes that could be measured in the marine environment. It was felt that a high magnitude change in distribution or population size would potentially be measureable within the Moray Firth as the baseline information for the area is robust. The duration of impact described has been agreed through consultation with Marine Scotland, SNH and JNCC.

A summary of the consultation process that was undertaken during the development of the impact assessment methodologies described in this document are provided in Table 3.4 below.

Table 3.4: Summary of consultations undertaken with key stakeholders

Consultee	Date	Purpose	Outcomes
SNH, JNCC & MS	10th June 2011	Baseline data presentation (in conjunction with BOWL)	After a detailed presentation of available data collected for baseline use of the Moray Firth by marine mammals, currently available impact assessment methodologies were discussed and population impact modelling discussed. MORL were advised to use publically available information for behavioural response to pile driving noise within any impact assessment for marine mammals.
SNH, JNCC & MS	28th June 2011	MFOWDG underwater noise methodology workshop	Presented noise modelling parameters and demonstrated potential of INSPIRE model.
SNH, JNCC & MS	23rd September 2011	Underwater noise workshop held in conjunction with BOWL	Presentation of Seal Assessment Framework and proposed revisions to methodology.
WDCS	27th November 2011 16th of March 2012	Joint meeting with BOWL to discuss assessment approach being developed	Discussion regarding proposed methodology, cumulative impacts of construction activities with MoD activities and distribution of minke whales within the Moray Firth.
WDCS	16th March 2012	Meeting to discuss draft ES submitted by MORL	Broad level agreement of approach taken by MORL. Provided additional points for clarification / expansion in ES.
SNH, JNCC & MS	19th March 2012	Meeting to discuss draft ES submitted by MORL	Broad level agreement of approach taken by MORL to develop assessment methodologies and support / request to extend to framework to include bottlenose dolphin. Detailed responses provided in Marine Mammal baseline section of the ES.
Offshore Wind and Underwater Noise Working Group	Ongoing	Bi-monthly meetings hosted by The Crown EState	MORL are contributing to wider, industry-led discussions on underwater noise including the development of methodologies for assessment and scoping studies to expand knowledge on issue.

3.1 Appropriate Assessment

Two SAC's listing marine mammals as qualifying features can be found within the Moray Firth. For the purpose of Appropriate Assessment, an appraisal under the Habitats Regulations can be found in Technical Appendix 7.3 G.

3.2 EPS Assessment

All cetaceans present within the Moray Firth are European Protected Species (EPS). MORL recognises that an EPS license will be required during the construction phase of the developments. A preliminary assessment regarding this can be found in Technical Report 7.3 H, which will be revised once construction parameters have been finalised.

4. Construction Phase Impact Assessment

4.1 Increased anthropogenic noise

4.1.1 Prediction of impact

Construction of an offshore wind farm will involve activities that will increase marine mammal exposure to man-made noise, for example, vessel engine noise, trenching, dredging, drilling and piling.

There is currently no publicly available information on marine mammal responses to trenching, but a number of behavioural responses to vessel traffic, drilling and piling have been reported. Coastal species such as harbour porpoise and bottlenose dolphin have been shown to respond to high levels of anthropogenic noise (e.g. Southall *et al*., 2007), suggesting marine mammals could be temporarily displaced from a preferred habitat in the Moray Firth as a result of an increase in anthropogenic noise during construction.

4.1.2 Characterisation of potential impact

For the purpose of this ES, estimation of levels of underwater noise from a potential wind farm development have been undertaken in two phases. The full methodology is described in Chapter 3.6 and Technical Appendix 3.6 A and summarised below.

Simple Propagation Estimator And Ranking (SPEAR) modelling was conducted by Subacoustech Environmental Ltd to rank the significance of a wide range of sources of underwater noise for key marine mammal species. The model uses estimates from the Subacoustech Environmental database of typical frequency content, source level and transmission losses associated with each type of activity to estimate how noise levels vary with range from the source. This estimated noise level is then used to predict the geographical area within which key species of marine mammal are predicted to respond to the noise.

The second phase of the analysis was to identify those activities with a noise source that would have the greatest impact on marine mammals and to determine whether their impacts warranted more in-depth investigation. Details of this second phase can be found in Section 4.2 of this document.

The activities used for the SPEAR model are summarised in Table 4.1. In each case, the "worst case" scenario has been used for each activity. Results are produced as an "index figure" which represents the area of sea, or distance from the source, within which marine mammals are predicted to respond as the result of noise produced by a particular activity.

The SPEAR model was run using a value of 90 dB_{ht}, a level which is predicted to cause strong avoidance in virtually all individuals, and 75 dB_{ht}, a level predicted to cause reactions by a lower proportion of individuals (Nedwell *et al*., 2007) (see Technical Appendices 7.3 B and 7.3 C for discussion). The species examined were:

- Harbour porpoise;
- Bottlenose dolphin;
- Harbour seal;
- Minke whale

For the purpose of this analysis and based on available information, harbour seals are also considered an appropriate proxy for grey seals in this context. For the minke whale, an audiogram was developed based on modelled audiogram for the humpback whale; see Section 4.2.2.2 for more details.

It was assumed that all activities were continuous over a 24 hour period apart from piling. Large (i.e. container ship, FSPO[2]) and medium (i.e. survey vessels >100 m long, small passenger ferry) sized vessels were modelled collectively, all travelling at a speed of 10 knots.

Table 4.1: Summary of parameters used for SPEAR modelling (Reproduced from Noise Technical Report 7.6A: Underwater Noise).

Activity	Parameters used for model
Impact piling[3]	• 4.4 hours driving per pile; • 2,500 mm (WTG jacket pin-piles); 3,000 mm (OSP pin piles) and 4,500 mm (Met Mast) diameter piles; and • 2 piles installed per day.
Vessel noise	• DP jack-up barge for piling, substructure and WTG/OSP installation; • Large and medium sized vessels to perform other construction activities i.e. diving support, anchor handling; and • Small vessels for crew transport and survey work on site.
Trenching	• Inter-array and export cable installation.
Cable laying	• Inter-array and export cable installation.
Drilling	• In case impact piling refuses.
Rock placing	• Installation of export cable; and • Gravity base structure (rock dumping inside gravity base structures).
Dredging	• Trailer suction hopper dredger for export cable installation.

The SPEAR model results identified piling as the activity which would have the greatest impact on the species under investigation, and confirmed that this impact would require further analysis. This analysis is discussed separately in Section 4.2 below and piling is therefore not considered further within this section.

[2] Floating production, storage and offloading unit – used in Oil & Gas industry for processing hydrocarbons and storing oil. Usually converted single-hull super tankers.
[3] A 2.5 m pin in the stiffest soil found on site was chosen for the modelling in order to present a credible 'worst case' scenario, see Underwater Noise Technical Appendix 7.6A for more details.

The numerical values from all of the SPEAR modelling can be found in Table 4.2. The results for piling are included for comparison. Background noise levels experienced by marine mammals within the Moray Firth are in the range of 30-55 dB_{ht}, depending on species and sea state (see Technical Report 7.6: Underwater Noise). Underwater measurements of background noise taken within the Moray Firth suggest that levels of background noise within the Moray Firth are typical for UK waters.

Visual representations of outputs at the 90 dB_{ht} value for minke whales, bottlenose dolphins, harbour porpoises and harbour seals are illustrated below (Figures 4.1a-d respectively). Piling noise has been omitted from these representations, as the scale of impact arising from this activity approximates to two times the order of magnitude of impact of other activities (as shown in Table 4.2).

Table 4.2: Numerical output from SPEARS model predicting and comparing the impacts of different construction activities on marine mammals.

Construction activity	Impact range (m)							
	Minke whale		Bottlenose dolphin		Harbour porpoise		Harbour seal	
	90 dB_{ht}	75 dB_{ht}	90 dB_{ht}	75 dB_{ht}	90 dB_{ht}	75 dB_{ht}	90 dB_{ht}	75 dB_{ht}
Suction dredging	16	180	21	72	21	200	2	26
Impact piling (2.5 m pile)	11,000	23,000	7,300	15,000	11,000	21,000	5,100	13,000
Impact piling (3 m pile)	12,000	24,000	7,700	15,000	12,000	21,000	5,400	14,000
Impact piling (4.5 m pile)	13,000	25,000	8,400	16,000	13,000	22,000	5,900	15,000
Cable laying	18	180	9	75	29	220	2	29
Rock placing	70	390	31	170	99	550	17	99
Trenching	59	390	81	350	140	640	12	87
Vessel noise	6	130	12	110	22	200	<1	11

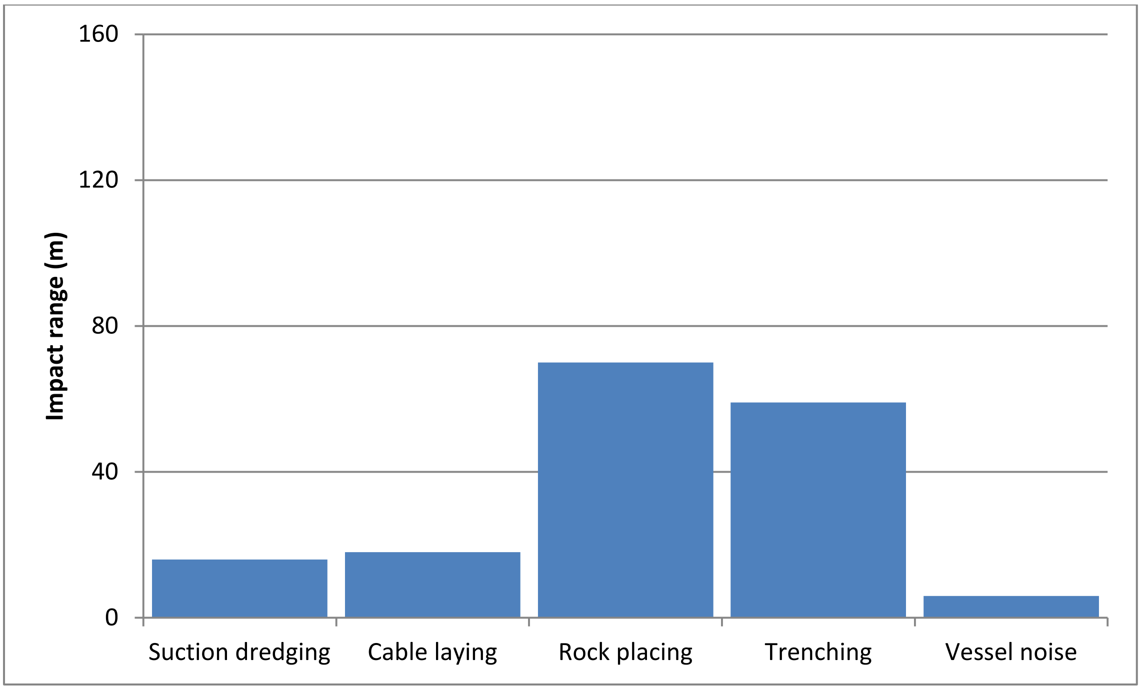

Figure 4.1a: Spatial extent of predicted impact ranges (90 dB_{ht} radii) of various activities on minke whales.

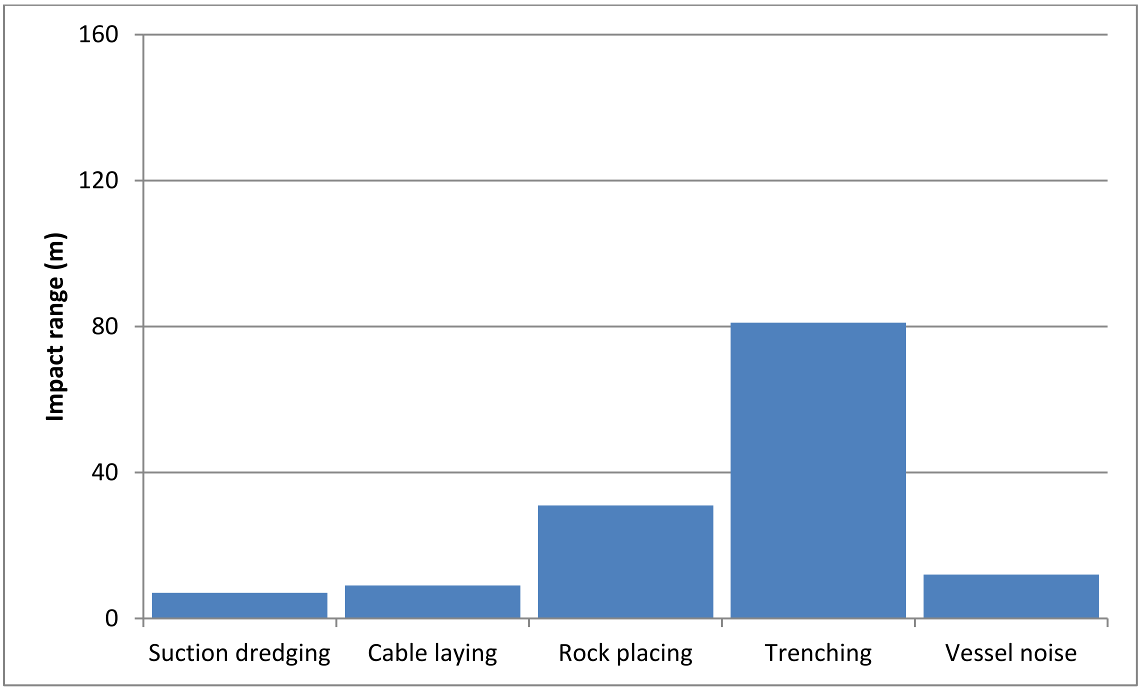

Figure 4.1b: Spatial extent of predicted impact ranges (90 dB_{ht} radii) of various activities on bottlenose dolphins.

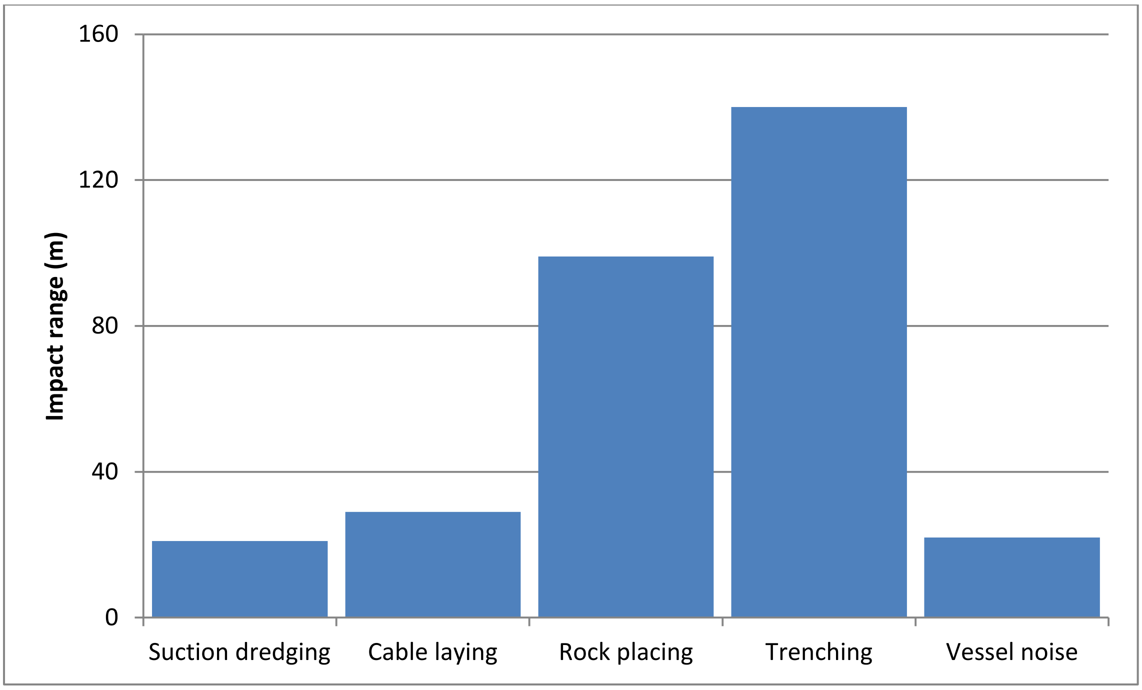

Figure 4.1c: Spatial extent of predicted impact ranges (90 dB_{ht} radii) of various activities on harbour porpoises.

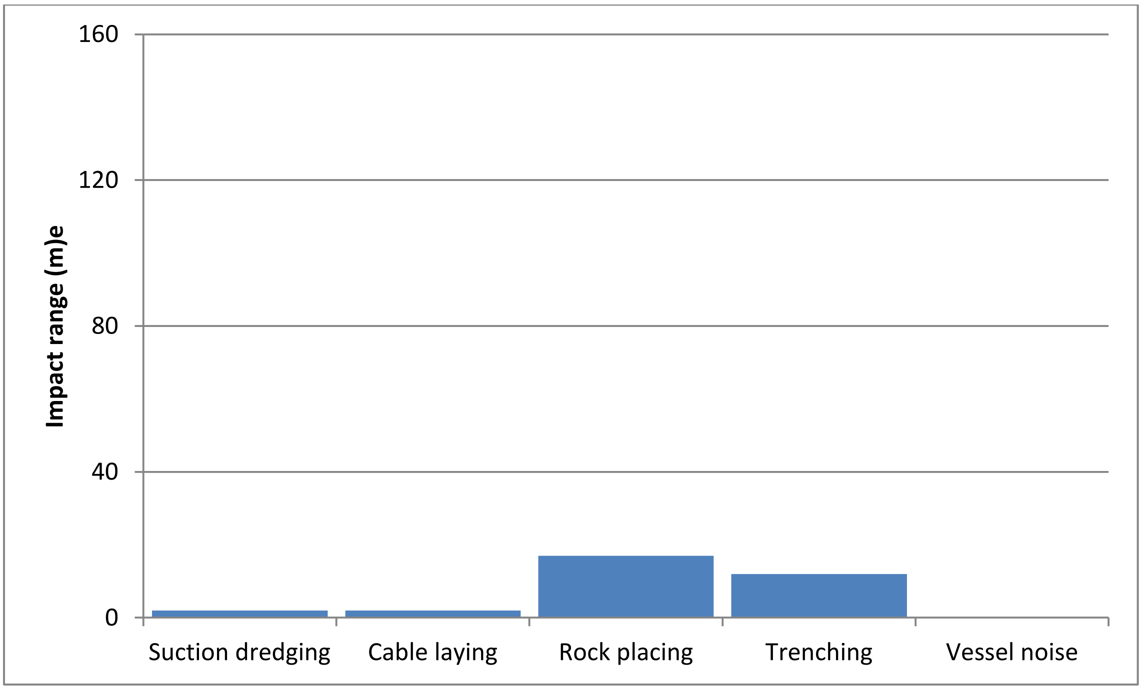

Figure 4.1d: Spatial extent of predicted impact ranges (90 dB_{ht} radii) of various activities on harbour seals.

4.1.3 Assessment of significance

Marine mammals have very good underwater hearing, and as a consequence are potentially sensitive to activities that increase underwater noise above background levels (Koschinski *et al*., 2003, Thomsen *et al*., 2006, Madsen *et al*., 2006). Cetaceans rely heavily on sound to feed, navigate and socially interact. Sound has the ability to travel much further underwater compared to in air, resulting in anthropogenic noise potentially affecting marine mammals at relative large distances from the source.

The impacts of underwater anthropogenic sound can be summarised into three broad categories:

- Behavioural avoidance;
- Auditory damage (temporary and permanent); and
- Physical injury and death.

The individual consequences of mortality are relatively clear; it is, however, more difficult to assess the biological consequences of behavioural responses and auditory injury.

Reported behavioural responses by marine mammals to anthropogenic noise include changes in foraging/diving behaviour, swim speed, respiration or vocalization; displacement and avoidance. Some of these responses can be subtle and difficult to detect, and there are many documented cases of apparent tolerance of anthropogenic noise (for example: Richardson *et al*., 1995; 1999; Madsen *et al*., 2002; Croll *et al*., 2001).

As described above, the SPEAR model was run using a value of 90 dB_{ht}, a level which has traditionally been predicted to cause strong avoidance in virtually all individuals, and 75 dB_{ht}, a level predicted to cause reactions by a lower proportion of individuals (Nedwell *et al*., 2007b) for four species; harbour porpoise, bottlenose dolphin, harbour seal and minke whale.

- For bottlenose dolphins, the largest predicted impact is from trenching activities with strong avoidance predicted within 100 m of noise sources tested and mild behavioural reactions up to 350 m.
- For harbour seals (and grey seals by proxy), the largest predicted impact is from rock placement activities with strong avoidance predicted within 20 m of noise sources tested, and mild behavioural reactions up to 100 m.
- Harbour porpoise are predicted to respond to trenching related noise, with strong avoidance predicted within 140 m from noise sources tested, and mild behavioural reactions up to 640 m.
- Minke whale are predicted to respond to rock placement activities, with strong avoidance predicted within 70 m of noise sources tested, and mild behavioural reactions up to 390 m.

There is currently no publicly available information on marine mammal responses to trenching or rock placement, so for the purpose of this assessment it is presumed the marine mammals will respond to such activities in a similar manner to those responses observed during interactions with vessels. It should also be noted that trenching and rock placement activities will be carried out from vessels, and so any response by marine mammals is likely to be a combined response to the associated noise sources.

Reports of behavioural responses to vessel noise are often associated with fast, unpredictable boats such as speedboats and jet-skis (Bristow & Reeves, 2001; Gregory & Rowden, 2001; Leung Ng & Leung, 2003; Buckstaff, 2004), with neutral reactions observed to larger vessels such as cargo ships (Leung Ng & Leung, 2003; Sini *et al* 2005). Short-term behavioural responses have the potential to have long-term consequences at both the individual and population level (Lusseau & Bejder, 2007) as added energetic constraints could impair vital rates and potentially affect population viability.

Responses include increased dive time (Janik & Thompson, 1996; Nowacek et al., 2001), erratic behaviour (Lusseau, 2006), changing direction of travel (Lemon *et al.,* 2006), displacement/avoidance (Lusseau, 2003; 2004). Bottlenose dolphin behaviour can become more erratic in the presence of vessels (Lusseau, 2006), a typical predator avoidance behaviour (Williams et al., 2002). It has even been suggested that dolphins may avoid areas completely because of an increase in the level of boat traffic, (Bristow & Reeves, 2001, Bristow, 2004). However, such responses are clearly open to interpretation and no studies have yet been carried out where there is a good understanding of other contributory factors such as changes in prey resources.

In contrast dolphins appear to tolerate cargo vessels in Hong Kong and Aberdeen, appearing to be habituated to the relatively high levels of boat traffic associated with the areas (Leung & Leung, 2003; Sini *et al*., 2005).

Primary Assessment

The basis of this assessment is that the noise produced during specified construction activities may elicit behavioural responses by marine mammals which could ultimately result in their distribution being altered. As previously discussed, the greatest source of anthropogenic noise during construction is predicted to be from piling, the impacts of which are discussed in more detail in Section 4.2.

Although the specific impacts of piling are not discussed here, it is proposed that, while this activity is occurring, piling will be the primary noise source and therefore will mask any potential impacts from other sources of noise, rendering them **insignificant**.

Rock placing and trenching are the two activities (aside from piling) that are predicted to cause behavioural responses at an appreciable distance from the source. These activities are primarily associated with cable burial and gravity base structure (GBS) placement and are unlikely to occur in the vicinity of piling activity. No specific responses to these activities have been reported to date so for the purpose of this assessment they are considered to be similar to those responses reported to the presence of boat traffic.

The SPEAR modelling suggests that avoidance by the majority of individuals present will be restricted to within 100-140 m of the noise source. Given the large area of habitat available to all species concerned (see Chapter 4.4: Baseline Marine Mammals), it is considered that the activities investigated here will not restrict marine mammal habitat to such an extent as to negatively impact any of the species under investigation.

Mild responses by a lower proportion of individuals are predicted to occur between 100-640 m from the source, depending on the species. Published responses to boat traffic suggest such reactions are likely to be temporary, although their long-term implications are unknown. Given the area of potential habitat available to the species under investigation, it is considered that sufficient habitat will remain available outside of the range of impact and any impacts will therefore be negligible.

The effects of anthropogenic noise other than piling during construction are predicted to occur only within a small radius of the source, to be of a **low magnitude** for all receptors and of **medium term duration**, both within the proposed wind farms and along the export cable route. These impacts are therefore predicted to be of **minor significance**.

4.2 Increased anthropogenic noise: Piling

4.2.1 Prediction of impact

The SPEAR model discussed in Section 4.1 illustrates that the construction activity that generates the highest level of underwater noise is pile driving associated with driven foundations and warrants further investigation into its noise propagation.

Piling involves hammering piles into the sea bed using an impulse driving technique at between 1 and 1.5 second intervals for several hours. The level of noise produced depends to a certain extent upon the blow energies required to pile the foundation, with the required blow energy dependent upon various factors including pile design and diameter, seabed characteristics and water depth (Diederichs *et al.,* 2008). The propagation of the noise produced through the water column is dependent upon various factors including the depth of the water (See Chapter 3.6 Underwater Noise and Technical Report 3.6A for full details).

A review of available information (Thomsen *et al*., 2006) suggests harbour porpoise and harbour seals may respond to piling noise up to 20 km away, with the potential for masking[4] of communication signals occurring well beyond 80 km. Similar predictions have been reported by a number of other studies in the North and Baltic Seas (Tougaard *et al*., 2003a, b, 2005; Madsen *et al*., 2006; Tougaard *et al*., 2009; Brandt *et al*., 2011). Marine mammals exposed to high levels of noise, close to the source, may also be physically injured (Thomsen *et al*, 2006; Madsen *et al.,* 2006).

Data presented in the papers above suggests that the pile driving during the construction of the MacColl, Stevenson and Telford wind farms will produce noise levels which have the potential to cause injury or elicit behavioural response by marine mammals (Richardson *et al*., 1995). This assessment is broken up into three discrete sections:

[4] When vocal signals cannot be heard by individuals due to high levels of background noise.

- Piling associated with offshore generating stations;
- Installation of a second offshore meteorological mast (met mast).
- Piling associated with offshore substations (OSP's) associated with Offshore Transmission Infrastructure (OfTI); and

A secondary assessment has been performed examining the potential effects of constructing the three proposed developments independently.

4.2.2 Characterisation of potential impact

The University of Aberdeen, SMRU Ltd, Natural Power Consultants and Subacoustech Environmental have developed, and have consulted with SNH, JNCC and Marine Scotland upon, a framework for assessing the impacts of piling noise on the Moray Firth harbour seal population. This framework has subsequently been developed to assess impacts on other marine mammals. This document forms the basis of the impact assessment on piling noise under discussion here, and is presented as Technical Appendix 7.3 B: Seal Assessment Framework.

4.2.2.1 Assessment approach

The general approach of the framework is illustrated in Figure 4.2 below, using harbour seal as an example species.

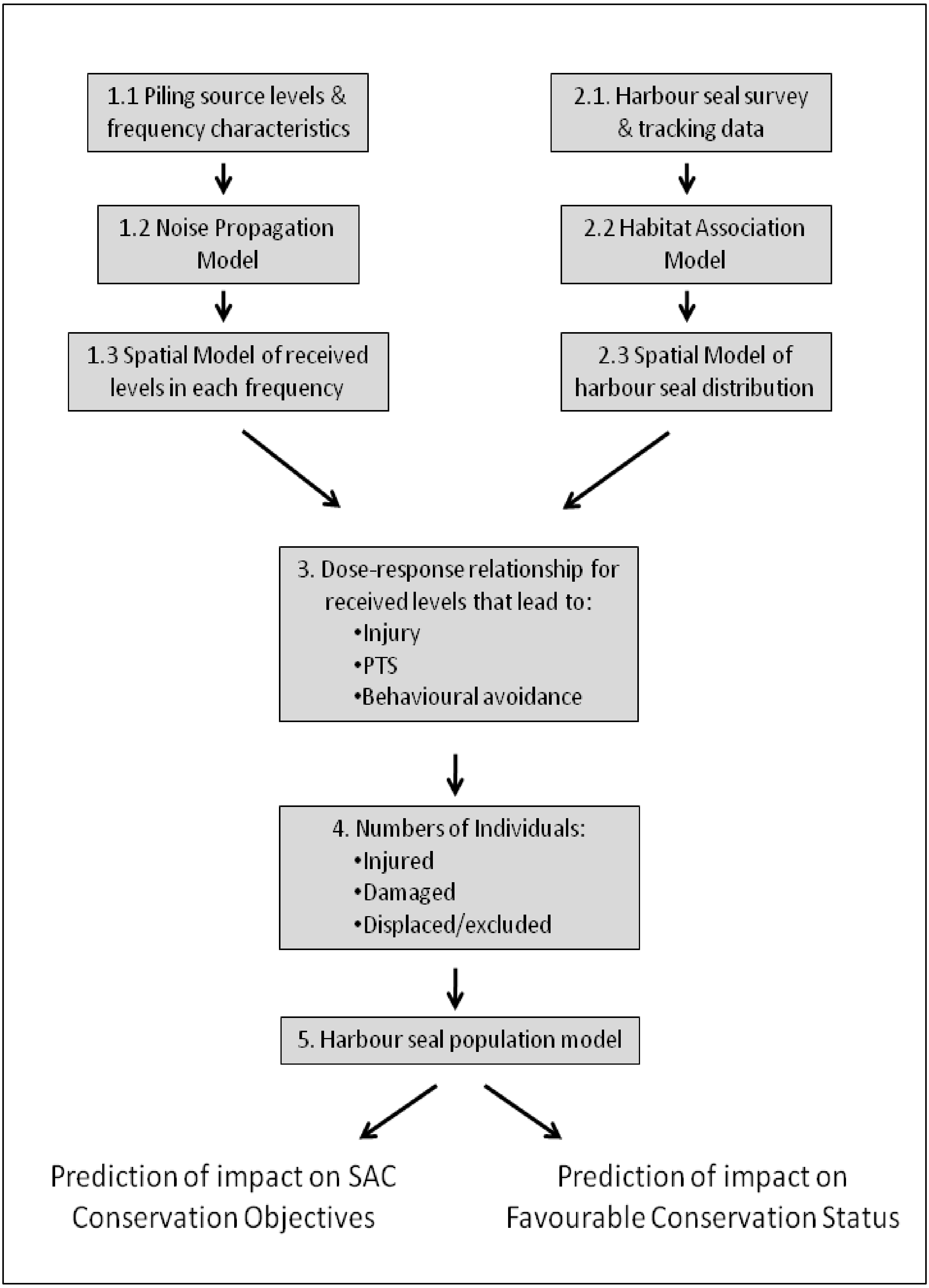

Figure 4.2: Schematic of the approach proposed for assessing the impact of wind farm construction on harbour seal SAC conservation objectives and Favourable Conservation Status (FCS).

Technical Appendix 7.3 B details the full methodology but a brief outline is described here.

Phase 1: Predicted noise propagation from piling was modelled using the Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model by Subacoustech Environmental Ltd. Blow energies and durations required for the installation of the pin piles in the Telford, Stevenson and MacColl sites are provided within the Technical Appendix 3.6 A: Underwater Noise. Ramping up of power (i.e. soft start with subsequent increases in blow energy in a step-wise manner to reach full blow energies) is included in the model parameters.

For behavioural response predictions, this model was then used to predict received noise levels (dB_{ht} by the receptor) in different parts of the Moray Firth. The dB_{ht} contours were generated at 5 dB_{ht} increments between 25 and 130 dB_{ht}.

The dB_{ht} contours were then used to estimate the maximum perceived level of noise in 4 x 4 km grid squares for which species density estimates are available (see Phase 2 below). Representations of these outputs can be found in Technical Appendix 7.3 F.

To make predictions of auditory injury (PTS), M-Weighted Sound Exposure Levels (SELs) (Southall et al 2007) were also modelled. The numbers of animals receiving sound levels sufficient for PTS onset was predicted using the programme Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna (SAFESIMM), which currently provides the best available representation of animal movements in response to noise (see Technical Appendix 7.3 C for details). In summary, SAFESIMM provides estimates of the number of individuals of each species that may experience PTS from a particular sound field (in this case piling) by simulating the three dimensional movements of thousands of simulated animals through this sound field, based on known characteristics of the diving and swimming behaviour of each species, and records the cumulative SEL of each simulated individual. The resulting model outputs (which utilise the density estimates described in Phase 2 below) are scaled to by the at sea animal density data to provide predicted numbers of individuals of each species that would be exposed to SELs sufficient to induce the onset of PTS.

Phase 2: The distribution of different receptor species was modelled using best available data in habitat association models - presented in Chapter 4.4 and corresponding Technical Appendix 4.4 A. These studies provided density estimates per 4 x 4 km grid square across the Moray Firth for all species considered within this assessment.

Phase 3: Publically available data, primarily the porpoise behavioural studies in response to piling noise at Horns Rev II (Brandt *et al.* 2011), enabled the generation of a dose-response relationship between received noise levels and the probability of avoidance/displacement. The details of this relationship and how it is has been used to model displacement are presented as Technical Appendix 7.3 B – Seal Assessment Framework.

Phase 4:

This phase combines the predicted noise levels within each 4 x 4 km grid square, the number of individual marine mammals of each species within each grid square, the proposed dose-response relationship described above in Phase 3 and the number of individuals predicted to experience the onset of PTS by SAFESIMM. For harbour seal and bottlenose dolphin, these data were then used within population models to assess how different construction scenarios might affect long-term population growth in comparison to baseline scenarios with no construction (see Technical Appendix 7.3 B for full methodology). For other species, the numbers of individuals predicted to experience a noise related effect were related to regional population sizes to assess the magnitude of impacts.

4.2.2.2 Noise propagation modelling

The Impulse Noise Sound Propagation and Impact Range Estimator (INSPIRE) model has been developed to model the propagation of impulse broadband underwater noise in shallow waters. This model was used to assess the ranges at which physical injury; auditory damage and behavioural responses, may occur as a result of piling within the three proposed developments. Outputs from the INSPIRE models were compared with published noise data from a pile driving event (Bailey *et al*., 2010), supporting the hypothesis that predictions for un-weighted peak levels provide a conservative prediction of propagation across the wider Moray Firth (see Appendix 7.3 B for details). The model was then used to predict received noise levels (by the receptor) in different parts of the Moray Firth (see Technical Appendix 3.6 C: Underwater noise).

A detailed description of the methods used to model noise propagation can be found in Technical Appendix 3.6 A: Underwater noise and is summarised in Chapter 3.6: Underwater Noise of the ES. These documents also contain a detailed description of the sound propagation modelling approach and sound criteria used within this impact assessment, namely dB_{ht} and M-weighted Sound Exposure Levels (SELs). Summary definitions can be found in Table 4.4. The present impact assessment will detail how these modelled noise propagation models can be interpreted with regards to impacts upon marine mammals.

Table 4.4: Simple definitions of the metrics used in noise propagation modelling. Reproduced from Technical Appendix 3.6 A.

dB_{ht} (*species*)	Developed as a means for quantifying the likelihood of behavioural impacts of a sound on a particular species i.e. takes into account species differences in hearing sensitivity at different frequencies. Nedwell *et al.*, 2007(b)
M-weighted Sound Exposure Level (SEL)	Sound levels heard by four functional groups of marine mammals are frequency weighted by removing frequencies outside the hearing ranges of each group i.e. high frequency (porpoises); mid-frequency (dolphins); low frequency (whales) plus pinnipeds. Based on Southall *et al*., 2007.

Some of the key factors taken into consideration during the modelling process are detailed below.

Audiograms used for noise propagation modelling

An important concept in marine mammal hearing is that of the "audiogram"; which describes the relationship between frequency and hearing sensitivity. Audiograms generally exhibit a U-shaped pattern with highest sensitivity at the bottom of the curve (e.g. see audiograms provided in Technical Appendix 3.6 A: Underwater Noise). In general, the region of highest sensitivity tends to reflect the frequencies that each species vocalises at. Baleen whales (which include minke and humpback whales) produce low frequency sounds with few signals extending above 10 kHz, while dolphins and porpoises produce mid and high frequency signal sounds across a very wide frequency including specialised clicks used for echolocation (Richardson *et al.,* 1995; Southall *et al*., 2007). Seals communicate below and above water, and are believed to hear best at frequencies of 1-30 kHz (Richardson *et al.,* 1995; Southall *et al*., 2007).

Subacoustech Environmental have summarised audiograms (Nedwell *et al*., 2007a) for a wide range of marine mammals to assess the ranges at which behavioural responses might be expected from construction related activities. Details of the audiograms used in this assessment can be found in Technical Appendix 3.6 A: Underwater noise. As discussed in the report, in cases where audiograms were not available for the species under investigation, surrogate data was used; these include grey seals and minke whales.

No single audiogram is available covering the full hearing range for grey seals and so the audiogram for harbour seal was deemed an appropriate surrogate.

There are currently no audiograms available for minke whales, therefore a literature review was conducted to obtain a modelled audiogram from a member of the same sub-order (baleen whales) based on inner ear anatomy and vocal range.

The humpback audiogram was compared to audiograms held on file by Subacoustech Environmental. The audiogram range was found to be of a similar shape to the seal composite audiogram (see Figure 4.3 below) but of a different sensitivity.

Subacoustech Environmental therefore increased the sensitivity of the seal audiogram by 12 dB to fall within the two humpback ranges provided by Erbe (2002), and MORL propose to use the resulting audiogram as a proxy for the minke whale in the absence of better data. The resulting proxy audiogram is shown below in Figure 4.4.

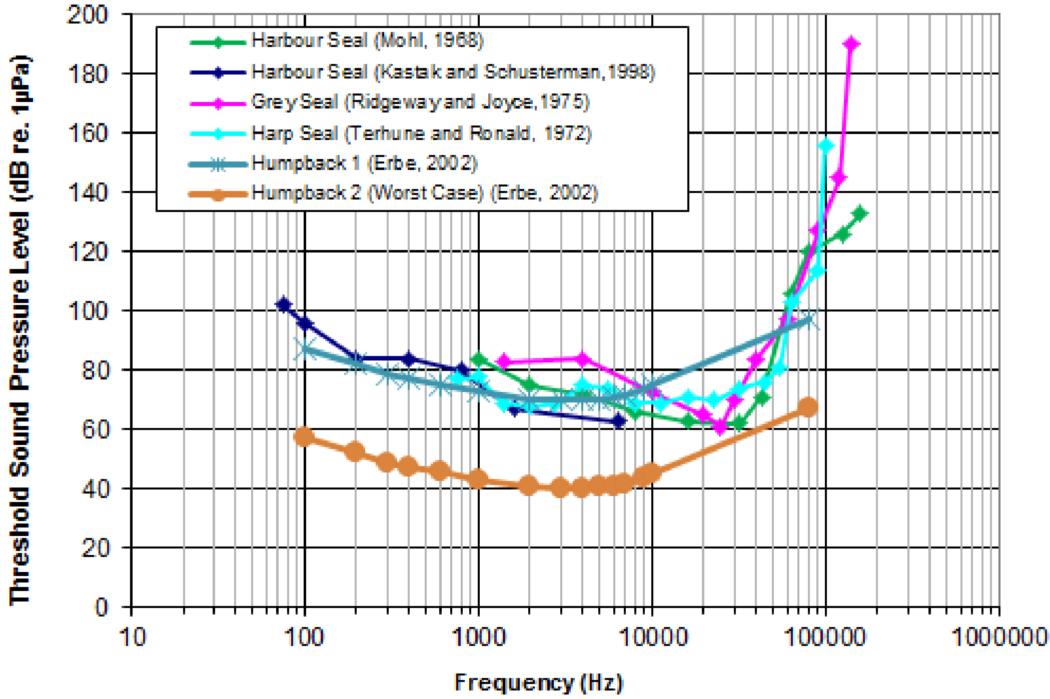

Figure 4.3: Humpback whale audiogram range and seal composite audiogram comparison.

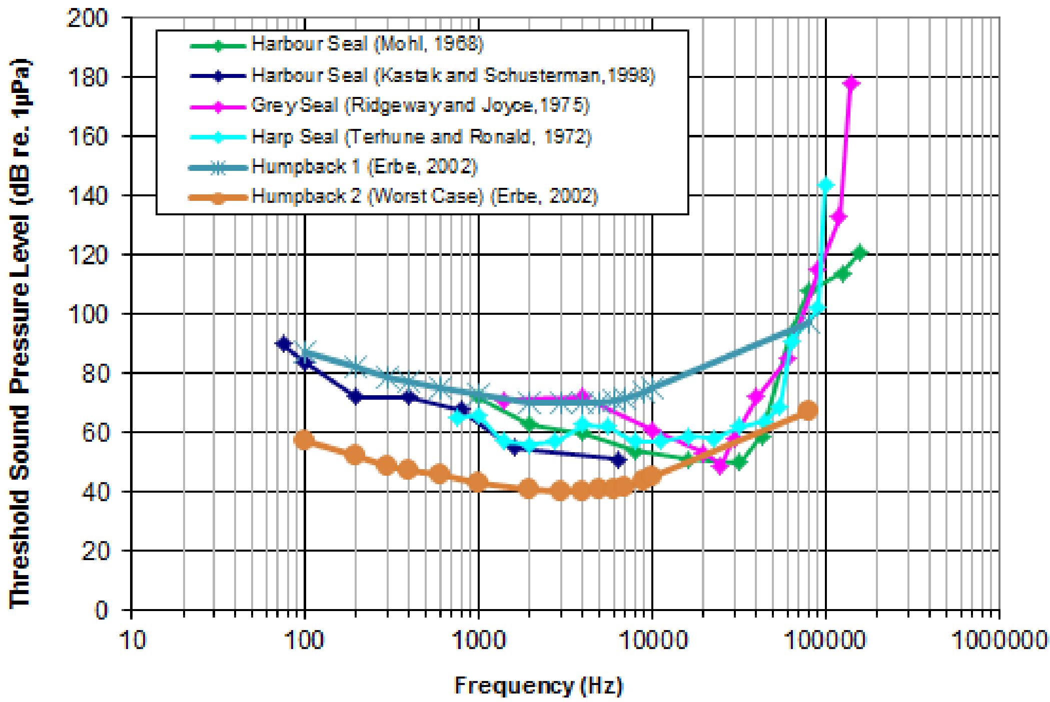

Figure 4.4: Humpback whale audiogram range and seal composite audiogram shifted by 12dB for comparison.

Criteria for assessing lethality and physical injury

In the absence of data from piling, data from blast exposures was used to estimate impact zones. Detail of the rationale behind this can be found in Technical Appendix 3.6 A: Underwater Noise. The following criteria were used:

- Lethal effects may occur where peak-to-peak levels exceed 240 dB re 1 μPa;
- Physical injury may occur where peak-to-peak levels exceed 220 dB re 1 μPa.

Lethality in marine mammals was predicted to occur within 2 m of a piling noise source and physical injury at 38 m.

Criteria for assessing auditory injury

Southall *et al.*, (2007) consider hearing damage can be predicted by an accumulation of noise exposure using SELs weighted by the hearing capabilities of each of four functional groups. Their proposed criteria can be found in Table 4.5 below. Impact zones resulting in auditory injury are estimated using these criteria.

Table 4.5: Proposed auditory injury thresholds for marine mammals (reproduced from Technical Appendix 3.6 A: Underwater noise).

Marine mammal group	Sound exposure level: multiple pulses
Low frequency cetaceans (i.e. minke whale)	198 dB re 1μPa^2.s
Mid frequency cetaceans (i.e. dolphins)	198 dB re 1μPa^2.s
High frequency cetaceans (i.e. harbour porpoise)	198 dB re 1μPa^2.s
Pinnipeds in water	186 dB re 1μPa^2.s

Criteria for assessing behavioural responses

Dose-response relationships were generated using the best available information to predict the proportion of animals likely to exhibit a behavioural response or develop permanent hearing damage (PTS) from an area due to piling noise. These curves were then combined with estimates of the distribution of animals within the Moray (see habitat modelling in Technical Appendix 4.4 A: Baseline marine mammals) to predict numbers that may be experience injury or PTS or exhibit behavioural responses as a result of piling noise.

Underwater Noise Model Parameters

Full details of rationale behind the parameters used in the noise propagation modelling can be found in Technical Appendix 3.6 A but in brief:

- Substrate 3 represents the stiffest soil type that can be found within the development zone and would require the highest piling blow energies;
- The Rochdale Envelope discusses two options for pile diameter (2 and 2.5 m) within the WTG, dependent on the turbine used. Although the impact radii estimated for both piles are similar in size (see Technical Appendix 3.6 A), a 2.5 m diameter was chosen to represent the worst case scenario. Offshore substation platforms will require a pile with a diameter of 3 m, the impacts of which are discussed in Section 4.2.3.3.

The predicted SELs are modelled assuming a level of noise, and so exposure to this noise, produced within a 24 hour period. As such, installation of one, two or up to four pin piles in a 24 hour window will impact the SEL and therefore the PTS predictions. It is likely that the Telford, Stevenson and MacColl construction programmes will involve between two and four pile installations per 24 hour window on each construction vessel.

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Modelling using INSPIRE to predict SELs from pile driving multiple, consecutive 2.5 m diameter pin piles into the stiff soil type of the Moray Firth in one 24 hour period showed that due to the logarithmic nature of the SEL equation, the majority of the noise exposure for animals that led to modelled onset of PTS occurred during the first piling. As piling of two pin piles per 24 hour period is considered to be most representative of likely construction activity on the MORL site (the majority of currently available construction vessels would drive two piles from one location and then be required to mobilise and reposition in order to pile the remaining two pin piles of each foundation),the modelled scenarios undertaken for the impact assessment process (and all other PTS onset modelling presented here) have been carried out using the example of two pin piles being installed consecutively per 24 hour window. Furthermore, it is considered that animals are likely to flee in response to piling and in relative terms, the predicted probability of PTS from the piling of two piles consecutively in any one 24 hour is considered to be representative of four consecutive piles.

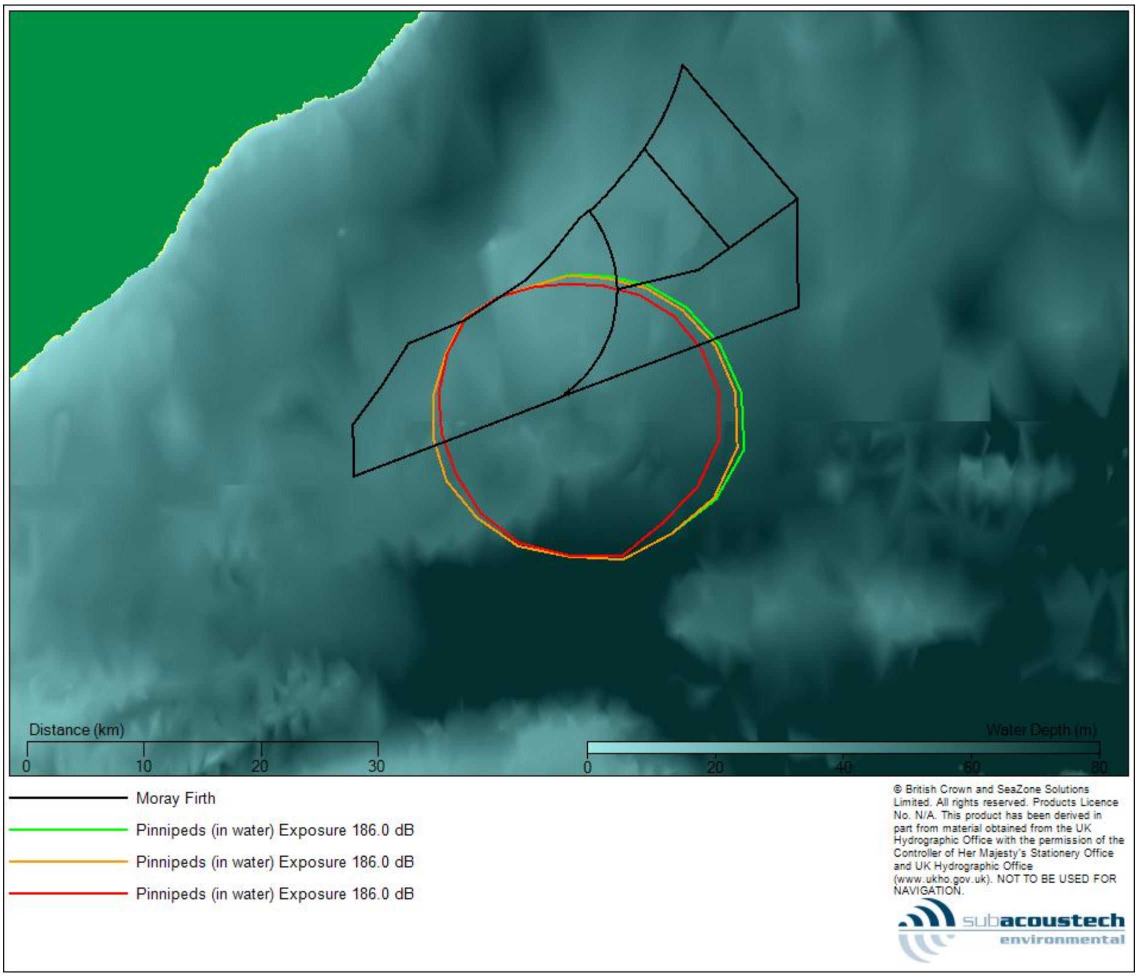


Figure 4.5: Comparison of maximum SELs for Pinnipeds in water (186 dB) based on one (red line), two (orange line) or four (green line) 2.5 m diameter pin piles being installed within a 24 hour period.

Table 4.6: Predicted 186 dB SEL ranges for seals from INSPIRE for one, two and four 2.5m diameter pin piles within a 24 hour period.

	1 pin	2 pins	4 pins
Area (km^2)	430	485	496
Maximum range (m)	14,800	15,400	15,800
Minimum Range (m)	9,400	9,700	9,700
Mean Range (m)	11,890	12,590	12,725

Details of the soft-start parameters used in the models can be found in Technical Appendix 3.6 A: Underwater noise. For clarity, soft-start was incorporated into the INSPIRE modelling, whilst the SPEAR model provides maximum noise levels associated to each construction related activity and thus does not include consideration of soft start.

4.2.2.3 Impact modelling on marine mammals

As discussed above in Section 4.2.2.2, full details of the methodology used to model the propagation of noise from piling, can be found in Technical Appendix 3.6 A: Underwater Noise.

The principles of how these modelled parameters were then used to model impact upon marine mammal species is discussed in Section 4.2.2.1 above. Following responses from Marine Scotland and the Statutory Nature Conservation Agencies (SNCAs), aspects of the framework were adapted, full details of which can be found in Technical Appendix 7.3 B: Seal Assessment Framework. These amendments are summarised as follows:

Behavioural displacement

The relationship (upper, lower and best fit estimates) between the probability of displacement and received dB_{ht} levels in each grid cell were used to predict behavioural responses. The upper fit is based on a modification of the parameters to provide a precautionary fit to the data points. The best fit uses the predicted coefficients from logistic regression and the lower fit uses the lower standard error of those coefficients. This provides precautionary upper, best and lower estimates of the number of individuals displaced for all the species assessed.

PTS

The modelling of individual marine mammals predicted to experience PTS onset was undertaken using SAFESIMM simulations and a 186 dB PTS onset threshold (see Technical Appendix 7.3 C for details). For harbour seals, a total population of 1,183 individuals was used and the predicted at-sea distributions were used with 25% of animals assumed to be hauled-out (see ES Chapter 4.4 & Technical Appendix 4.4 A for details).

The same approach described for harbour seal was also applied for cetaceans. For harbour porpoise, bottlenose dolphin and minke whale the estimated numbers of each species to experience PTS are based on the SAFESIMM models using 198 dB onset thresholds. Densities are based upon the information provided in Technical Appendix 4.4 A: Baseline marine mammals. Data on spatial variation in bottlenose dolphin density is presented in Technical Appendix 4.4 A: Baseline marine mammals and it was assumed that 50% of the east coast population were present within the Moray Firth. Values for the percentage of population affected relate to the entire population. Minke whale densities are based upon the SCANS II estimate of 0.022 individuals/km^2 across the whole Moray Firth and the population upon which the assessments are made is the modelled abundance estimate (1,462) for the SCAN II Block J (which includes the Moray Firth).

Population Modelling

Information on the number of individuals displaced or experiencing PTS was then used in population models to assess the long-term impacts upon harbour seals and bottlenose dolphin populations. To achieve this, certain assumptions had to be made about how exposure to noise might influence demographic parameters. For example, displacement may influence the energetic cost of foraging and lead to a reduction in reproductive success, whilst PTS may influence the ability of animals to find food or avoid predators and thus lead to an increased risk of predation. A full discussion on this process can be found in Technical Appendix 7.3 B: Seal Assessment Framework. These long term impacts were assessed over a period of 25 years, as this represented the predicted life span of the developments and is in line with published data on marine mammal life expectancies of both harbour seals and bottlenose dolphin (see Technical Appendix 7.3 B).

For harbour seals, a deterministic stage-based matrix model previously used to estimate the impacts of shooting seals was adapted (Thompson *et al*., 2007), enabling potential changes in reproductive output and mortality specific to certain age-classes or sex to be explored. The model also allows the incorporation of cumulative impacts; for example, if licences to shoot seals within the Moray Firth are granted (see Technical Appendix 7.3 B for details).

The bottlenose dolphin model used a stochastic individual-based model previously used to compare management strategies for the Moray Firth bottlenose dolphin population (Thompson *et al*., 2000). This uses available literature values for bottlenose dolphin demographic and life-history parameters in the programme VORTEX to produce a baseline model with a stable population growth rate (see Technical Appendix 7.3 B for full details).

For both species, assessments compared baseline models (see Figure 4.5 below) to different impact scenarios in which the effects of displacement and PTS were modelled as a direct impact on survival and reproduction success (see Technical Appendix 7.3 B for details). The upper graph in Figure 4.5 represents output from the harbour seal baseline population model which demonstrates that, in the absence of construction noise, the harbour seal population of the Moray Firth is predicted to continue to increase until the carrying capacity of the habitat is reached.

The outputs of the bottlenose dolphin population model differ in appearance to those from the harbour seal model. The baseline bottlenose dolphin VORTEX model was run 1000 times, and the outputs are summarised in the lower histogram of Figure 4.5 which illustrates the frequency distribution of predicted population sizes after 25 years.

Incorporating the impacts of noise into population models

Population models for both species used the same broad precautionary approach for incorporating the impacts of PTS and displacement.

a) 25% of the animals with PTS will suffer mortality during the year of exposure and

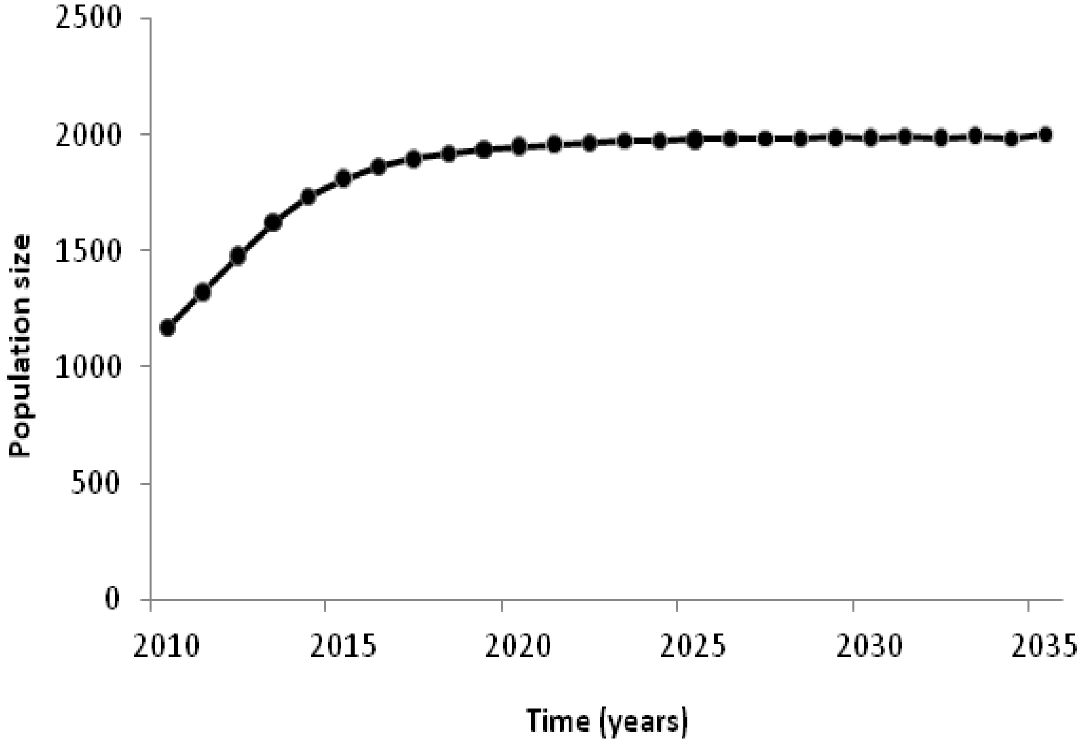
b) That all females predicted to exhibit behavioural responses do not breed or they produce offspring that do not survive during the year of exposure.

A review of these, and other precautionary assumptions made throughout the development of the assessment methodology described here, is provided below in Table 4.7. The population model for harbour seals was also used to undertake a sensitivity analysis of the key assumptions within the model. This sensitivity analysis included varying the survival probability of harbour seals experiencing PTS. While different mortality rates resulted in different predicted population sizes during the construction phase, the long-term population projection was similar in all cases. As a result, a value of 25% mortality was used as a conservative estimator.

The sensitivity of the model to changes in carrying capacity[5] of harbour seals within the Moray Firth were also investigated. This showed that the difference between baseline and impact population sizes during construction is strongly affected by assumptions made with regards to carrying capacity. For the purpose of this assessment, a carrying capacity of 2000 was used for harbour seals and 400 for bottlenose dolphins. In both cases this is approximately double the current population estimates.

The current levels of licensed shooting are included in both the baseline model and all pile-driving scenarios for harbour seals.

[5] The **carrying capacity** of a biological species in an environment is the maximum population size of the species that the environment can support.



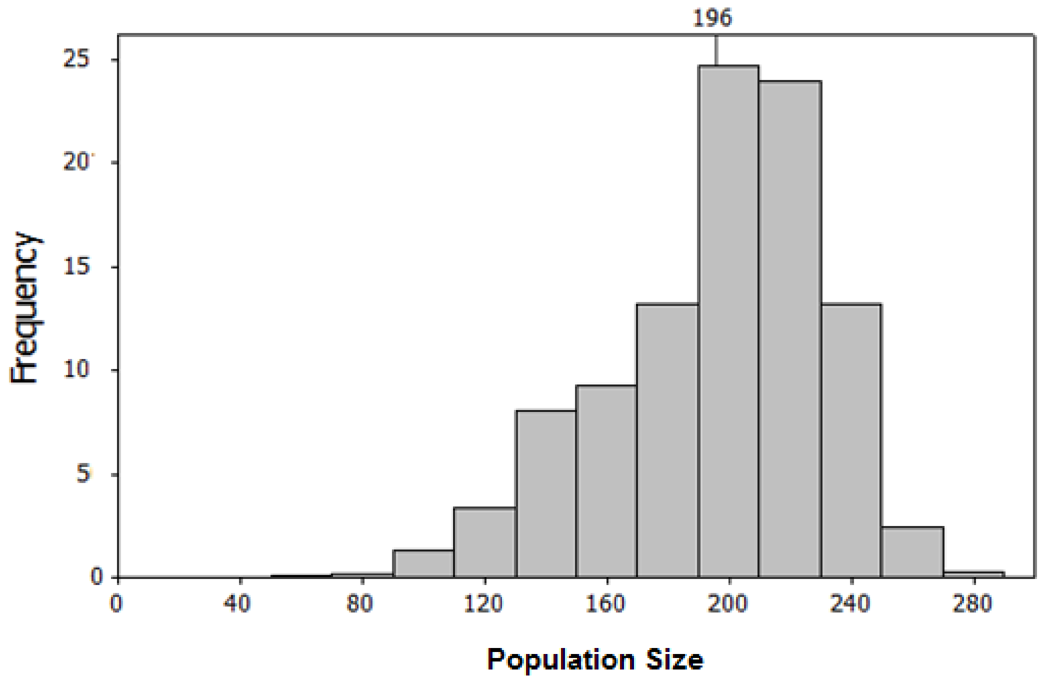


Figure 4.5: Baseline models against which scenarios are compared. Top = harbour seal; bottom = bottlenose dolphin. The harbour seal graph (top) shows the predicted population size in the absence of the proposed wind farm construction and how this varies across time. The bottlenose dolphin graph (bottom) shows the range of predicted population sizes in the year 2035 in the absence of the proposed wind farm construction.

4.2.2.4 Certainty in predictions during the assessment

As described above in Section3: Impact Assessment Methodology, the IEEM guidance (IEEM, 2010) provides criteria to be used when assigning certainty to predictions of potential impacts. Due to the number of conservative assumptions that have been made during the impact assessment for marine mammals, consultation with scientific experts has resulted in an assignation of a **probable** degree of certainty of impacts. Further, if the IPCC guidelines were to be followed (see Technical Appendix 7.3 G), a **likely** degree of certainty (66-100% probability) has been assigned to the predictions. The scientific experts involved in the development of the assessment methodology suggest that the conservative nature of all the assumptions taken result in a substantial cumulative over-prediction of impact. Table 4.7 below provides details on the assumptions that have been made during this impact assessment, and why they represent the most conservative approach possible in each case.

Table 4.7: Assumptions made during the impact assessment on marine mammals and their degree of conservatism

Assumption		Conservatism
1	Noise modelling used blow energies required to drive piles into the stiffest of the three soil types present on site throughout assessment.	The blow energy required to drive piles into stiffer soil types is greater than that required to drive them into softer soil types. As a consequence, higher noise levels are predicted from pin pile installation in the stiffest soil types. However, the degree of complexity required to model different blow energies in different regions of the sites, over an uncertain build duration, was prohibitive. As a consequence, worst case has been used throughout.
2	INSPIRE noise propagation modelling is conservative over the 20-50km range.	As shown in Technical Appendix 7.3 B, comparison of INSPIRE model predictions with published measured recordings from the Beatrice Demonstrator (Bailey *et al.*, 2010) indicate that the model predictions for unweighted peak levels provide a relatively good fit of the measured data. Modelled and measured noise levels correlate well at distances up to 20km from the piling event, but provide a conservative prediction of sound levels across the wider Moray Firth (20-50km).
3	Noise modelling locations to represent indicative piling activity have always been chosen to be closest to sensitive receptors or produce the largest spatial extent of effect.	This approach introduces an inherent conservatism over the duration of the construction phase. For example, for Scenario A described above in Table 7.3.7, a single location closest to the sensitive receptors (bottlenose dolphin and harbour seal) has been chosen and effects modelled to occur for five years. This is an over-estimation of effect, as the majority of piling would be more distant than this most sensitive location. In a similar conservative manner, the two piling locations for Scenario B (Table 7.3.7) have been chosen to represent the largest possible noise footprint from piling operations. Effects from Scenario B have been modelled to take place for three years. In practice, if two piling vessels were used on site they would operate in relatively close proximity to each other reduce vessel spread and transit time of support vessels, thus producing a significantly reduced noise footprint.
4	Allocation of	Technical Appendix 7.3 F illustrates how the modelled

Assumption		Conservatism
	perceived noise level to each 4x4km grid square used for marine mammal displacement modelling always used the highest level predicted for each square.	perceived noise levels for each species under individual construction scenarios were allocated. A perceived noise level that equated to the highest dB_{ht} radii that touched the 4x4km grid square was assigned to each square, rather than allocating a dB_{ht} level that corresponded to the greatest proportion of the square.
5	Degree of displacement from piling associated noise	As described in Technical Appendix 7.3 B, a precautionary fit has been applied to the porpoise displacement data gathered during the foundation piling at Horns Rev II and used to generate a dose response curve for porpoise displacement against perceived noise levels within the Moray Firth. The use of this precautionary fit to generate the dose response curve results in a higher level of modelled displacement than the best fit curve to the data, and therefore represents a conservative assumption in the modelling that has been undertaken.
6	Harbour porpoise behaviour was used as a proxy for bottlenose dolphin in the modelled disturbance from piling noise.	As described in Technical Appendix 7.3 D, analysis of available data indicates higher level responses by harbour porpoises than bottlenose dolphins to similar noise levels. Thus, using harbour porpoise as a proxy for bottlenose dolphin is likely to produce an overestimation of associated effect upon the bottlenose dolphin population.
7	Modelled avoidance of areas predicted to experience high piling related noise for the full duration of the construction period (i.e. animals modelled to not return in between periods of piling)	No data are currently available on the period of time that will elapse between the cessation of piling activity and the return of animals displaced from Smith Bank. Animals have therefore been modelled to remain excluded for the full duration of the construction period (i.e. a number of years). It is considered likely that animals will return between some piling events, especially during breaks in construction activity (e.g. due to bad weather). Assuming displacement for the entire construction period therefore represents a highly conservative assumption.
8	Effect of displacement upon reproduction rates of harbour seal and bottlenose dolphins	Population modelling has been undertaken to assess the population consequences of effects experienced by individual harbour seals and bottlenose dolphins. Animals modelled as being displaced for the full construction period have been assumed to either fail to produce young or for the young produced to not survive. This is considered to be a conservative assumption, at least in part due to the considerations described above (that the animals are displaced for the entire duration of the construction phase, and do not return to favoured feeding grounds in periods of no construction activity such as that induced by bad weather).
9	The 186 dB SEL criteria was used for modelling the number of individual seals exposed to noise of sufficient volume and duration	As described above and in Technical Appendix 7.3 E, the scientific advisors working with MORL reviewed the available literature for the rationale supporting the 186 dB SEL criteria for seals. They concluded that the evidence did not support the differential sensitivity of seals over cetaceans, and proposed a common criterion (198 dB SEL) for all species assessed. Peer and stakeholder

Assumption		Conservatism
	to induce PTS onset.	consultation on this approach concluded that while there was general agreement that the 186 dB SEL criteria was likely to be overly conservative, there was little evidence to support reducing the criteria to 198 dB SEL. It was generally agreed that the likely criteria for the noise exposure and duration to induce PTS onset would be somewhere between the 198 and 186 dB SEL level (see values provided in Table 7.3.9). As a result of this consultation the 186 dB SEL has been used here as a conservative modelling scenario (recognising that there is likely to be an over estimation of numbers of seals modelled to experience the onset of PTS).
10	SAFESIMM was used to model the number of individual animals which would experience noise levels sufficient to induce PTS onset	As described in Technical Appendix 7.3 C, SAFESIMM estimates for the number of individual seals experiencing PTS from piling noise are of an order of magnitude higher than those calculated using INSPIRE generated SEL radii. While both models use the same impact criteria (dB SEL levels), this difference is likely to be a consequence of the way INSPIRE and SAFESIMM model the fleeing behaviour of animals. In the INSPIRE model, the animal flees at a speed of 1.5m/s away from the noise source. In the SAFESIMM model, animals make 'randomised walk' movements away from the noise source, and take significantly longer to leave the area affected by noise of sufficient volume to induce PTS. Furthermore, seals in SAFESIMM continue to receive a noise dose regardless of whether they were diving or at the surface, when in reality animals (seals) at the surface will have their heads above the water and therefore not receive this dose. The use of SAFESIMM to estimate the number of individuals exposed to sufficient noise to induce PTS therefore represents a conservative element of the impact assessment methodology.
11	Consequence of PTS is a 25% risk of mortality.	The PTS onset criteria proposed by Southall *et al.,* (2007) represents an estimate of the noise levels at which a reduction in hearing acuity may start to occur. There are no empirical data on actual levels of PTS in marine mammals, or on whether such hearing impairment may affect their survival Based upon discussions with scientists and other stakeholders, the 25% mortality risk used in these models is considered highly conservative, but has been used due to the degree of uncertainty surrounding the consequences of these criteria.

4.2.2.5 Further work

MORL intends to install a met mast on a 4.5 m monopile foundation within the Stevenson site during a period of two weeks in August or September 2012, and will take the opportunity to participate in surveys designed to reduce some of the conservatisms in the assumptions made above.

MORL will deploy equipment to measure underwater noise propagated through the water column from the piling event at locations both near to the met mast installation (750 m) and further afield (up to 50 km). These will be correlated with the detailed records of the blow energies required to install the met mast foundation, and used to quantify any over-conservative predictions of perceived noise at distant locations from the piling events. The aim of this study is to quantify any over estimation of noise that may have occurred through the conservatism identified in assumption 2 in Table 4.7 above.

DECC have funded the deployment of up to 50 C-PODs by Aberdeen University that will be located in two linear arrays between 750 m and 25 km from the met mast location in the Moray Firth. The results from the analysis of the data collected from these C-PODs before, during and after the met mast construction will be used in conjunction with the noise measurement described above to refine the noise dose response curve for harbour porpoises to the received noise from piling of the monopile foundation. The C-PODS will be deployed up to three weeks prior to piling activity, and left in situ for up to three weeks after piling has ceased. This up to seven week deployment will establish the distribution of harbour porpoise before, during and after the piling event, and thus provide information to aid reduction in the conservative assumptions of 5 and 7 in Table 4.7 above.

In addition to the above survey work, MORL also intend to commission aerial photography along a linear transect route to provide data on the noise dose response for seals to piling noise. Unlike harbour porpoises, seals do not constantly vocalise and so their presence or absence will not be detected by C-PODs. Aerial photographs will record seals on, or near to, the surface of the sea along the transect route immediately before, during and after the piling event. It is hoped that this will provide information upon baseline use of the transect route, displacement due to perceived noise levels and an indication of the length of time needed for the seals to return to the vicinity of the piling site. While the results of this study will be qualitative rather than quantitative, they will go some way towards providing confidence to reduce the conservative assumption 7 in Table 4.7 above. A caveat to this proposed study is that it requires a good weather window during the piling of the monopile. Should wind and wave conditions allow piling to take place, but the cloud cover be low to prevent aerial photography, piling will take place in the absence of aerial photography.

It is also hoped that information to be made available from the DECC funded, SMRU harbour seal tagging study within the Wash will provide information on how harbour seals react to anthropogenic noise sources associated to the construction of offshore wind farms (including piling) and thus provide information to validate assumption 7 in the Table 4.7 above.

MORL also recognise that the robust baseline data available to themselves and BOWL for the undertaking of the impact assessment described above utilises data sources funded through a variety of studies and initiatives. These studies, and the funding bodies responsible for them, are identified within Technical Appendix 4.4 A and summarised below.

Bottlenose dolphins. Annual photo-identification surveys have provided information on changes in bottlenose dolphin abundance since 1990. Initiated as a collaboration between Aberdeen University and SMRU, this project has since involved a wide range of regional and international partners.

These surveys have allowed individual dolphins to be monitored for over 20 years, providing information on reproductive rates, survival and movement patterns between the Moray Firth and other parts of their range, including the Firth of Forth.

Since 2005, these studies have been complemented by passive acoustic monitoring, providing fine-scale data on changes in the occurrence of both dolphins and harbour porpoises at a series of core-sites within and outside the Moray Firth.

Harbour seals. Since 1987, annual counts have been made at harbour seal haul-out sites during both the pupping season and moult, providing detailed information on trends in abundance and changes in distribution. The first 20 years of this time-series were based upon land-based surveys, carried out by Aberdeen University. Since 2006, annual data have been collected through aerial survey as part of SMRU's national seal monitoring programme.

Following the development of a new pupping site in Loch Fleet NNR, photo-identification studies of individually recognisable harbour seals were initiated in 2005. Detailed annual surveys have now monitored the reproductive success and survival of over 60 different females. Information on variation in the timing of pupping, lactation duration and pup survival provide important indicators of environmental changes that would be impossible to collect at most other sites in the world.

In some years, this information is complemented by tracking data on foraging distribution. New developments in GPS technology mean this work can be built upon with increasingly high resolution data, for example to assess individual responses to construction noise. Such tracking data will be especially valuable because they can be integrated with information on these individual's previous reproductive history and subsequent survival.

Maintaining this survey effort through the pre-construction, construction and post construction phases (2012-2020) would enable robust assessment of the population consequences of the construction phases of both the MORL and BOWL offshore wind farm projects on bottlenose dolphins and harbour seals. However, the above datasets represent a huge survey effort and cost, and it is not considered appropriate that this maintenance of survey effort should fall to any one developer or funding body. MORL are currently exploring the potential for developing such studies in collaboration with other developers, Government, and other funding bodies.

Through the studies identified above, MORL would seek to inform the population parameters used within the existing framework for modelling the construction impacts upon marine mammals within the Moray Firth (Technical Appendix 7.3 B) and refine the assumptions presented above (Table 4.7). Like the methodology described within this impact assessment, this information would then be available to other developers of offshore wind and marine renewable energy devices to inform impact assessment processes in the future.

4.2.3 Assessment of significance

As discussed in Section 3 above, a level of significance for the impact of each scenario is predicted, based on the information provided by the modelling outlined above and available knowledge of the populations in question. The impacts of piling noise will be examined over three time durations:

- Short term – effects predicted for a few days or weeks i.e. single foundation;
- Medium term – effects predicted for months to a few years i.e. construction phase; and
- Long term – effects predicted for 25 years i.e. duration of wind farm.

The magnitude of impact will be assessed based on the proportion of the population that is predicted to be displaced or develop PTS compared to the baseline population level:

- High magnitude – greater than 20% of the population will be affected;
- Medium magnitude – between 10-20% of the population will be affected; and
- Low magnitude – less than 10% of the population will be affected.

By assigning a magnitude and duration, it has been possible to predict a significance of effect, see Table 3.2 on in Section 3 for detail.

4.2.3.1 Review of published responses of marine mammals to noise

Seals

There have been relatively few studies on the effects of pile driving noise on harbour seals. Tagging studies conducted at the Horns Rev development in Denmark found no evidence of avoidance of construction at the scale of tens of kilometres, although visual surveys of seals suggested changes in numbers at haul-out sites (Tougaard *et al*., 2006c). Similarly, recent studies at the Scroby Sands offshore wind farm reported declines in numbers of harbour seals at nearby haul-out sites (within 2 km of the construction site[6]) during wind farm construction; however, this relationship was complicated by marked increases in grey seal numbers at the haul-outs during the same period (Skeate *et al*, 2012).

Although no data are available from peer reviewed publications, some, observations have been reported of behavioural and physiological responses of harbour and grey seals to seismic survey airguns which, like pile driving, are high source, pulsed sounds (Thompson *et al*. 1998). These researchers (Thompson et al., 1998) conducted one hour controlled exposure experiments with small air

[6] The observations of this study are viewed in context with the proposed construction within the Moray Firth. The haul out locations for seals in the Moray Firth are in excess of 55km from the proposed MORL wind farm sites, and seals are not expected to be displaced from their haul outs during the construction of the Telford, Stevenson and MacColl wind farms.

guns (source levels of the air guns used were 215-224 dB re: 1µPa peak-to-peak) to eight harbour seals that had been fitted with telemetry devices. The telemetry packages allowed the movement, dive behaviour, and swim speeds of the seals to be monitored and thus provided detailed data on their responses to seismic pulses. Two harbour seals equipped with heart rate tags showed evidence of a physiological responses when playbacks started: their heart rates dropped dramatically from 35-45 beats/min to 5-10 beats/min. However, these responses were short-lived and returned to normal relatively quickly. The majority of harbour seals (75%) exhibited strong avoidance behaviour, swimming rapidly away from the source. Stomach temperature tags also revealed that they ceased feeding during this time. Only one seal showed no detectable response to the guns and approached to within 300 m of them. The behaviour of harbour seals seemed to return to normal soon after the end of each trial.

Similar avoidance responses were documented during trials involving grey seals; which changed from making foraging dives to dives typical of transiting and moved away from the noise source. Although some seals hauled out; those that remained in the water appeared to return to pre-trial behaviour within two hours of the guns falling silent (Thompson *et al*., 1998).

By contrast, sightings rates of ringed seals from a seismic vessel in shallow arctic waters showed no difference between periods with the full array, partial array, or no guns firing (Harris *et al*., 2001). However, mean radial distance to sightings did increase during full array operations, suggesting some local avoidance. Similarly, there appeared to be no observable responses by ringed seals to pipe driving noise; however, this noise, although similar in its pulsed nature to pile driving, has far lower source levels than pile driving. Underwater Sound Pressure Levels (SPLs) were 180 dB *re*: 1 µPa at all distances. During 55 hours of observation, 23 observed seals exhibited little or no reaction to any industrial noise except approaching Bell 212 helicopters. Ringed seals swam in open water near the island throughout construction activities and as close as 46 m from the pipe-driving operation (Blackwell *et al*., 2004).

In conclusion, there are no data available from harbour seals on at-sea behavioural responses to pile driving. However, on-going work by SMRU on harbour seals in The Wash should provide important new data as tracking studies are being carried out around piling operations at a wind farm construction site. These results will be directly relevant to this assessment. Some inferences can be made to responses to other pulsed sounds by harbour seals and other seal species. These suggest that animals are likely to exhibit behavioural responses by moving rapidly away from pile driving sounds, and that the proportion of animals responding will decrease as a function of received noise level.

Cetaceans

To date, the only species of cetacean that has been studied with respect to the construction impacts of offshore wind farms has been the harbour porpoise. Much of this work has been carried out in Denmark (Horns Rev I, II and Nysted offshore wind farms), but some studies were also conducted in the Moray Firth during the Beatrice Demonstrator Project (Thompson et al. 2010).

Porpoise are present in relatively high numbers in the vicinity of Horns Rev wind farm. Passive acoustic monitoring (T-POD) data collected during construction of Horns Rev I showed no significant changes in relative abundance of porpoise in the wind farm area as a whole during the construction period (Tougaard *et al*., 2006a), but there was evidence of changes in porpoise occurrence between piling and non-piling periods. Both visual and acoustic surveys indicated that these responses during construction were weak, negative and local, with activity returning to normal after a period of between 6-8 hours (Tougaard *et al*., 2006a). T-POD data collected during the construction of Horns Rev II (Brandt *et al.* 2011) has been utilised in the noise dose response curve described in Technical Appendix 7.3 B.

Porpoises are less abundant within the Baltic Sea and in the vicinity of the Nysted wind farm. T-POD data collected during the construction phase at Nysted showed a more pronounced decrease in relative abundance during construction, both within the wind farm and the reference site (Tougaard *et al*., 2006b; Carstensen *et a*l., 2006). In contrast to Horns Rev I, measures of relative abundance returned to baseline only after a period of several days rather than a period of hours (Tougaard *et al*., 2006b). It has been suggested that the recovering period for porpoise at Nysted was longer compared to Horns Rev as the food availability at the both sites was different and thus the motivation to return to the Horns Rev area was greater than for Nysted (Teilmann *et al*., 2006b).

As outlined in Technical Appendix 4.4 A: Baseline Marine Mammals, porpoises occur regularly over the Smith Bank in the Moray Firth. In 2006, piling was carried out in this area during the installation of the two substructures for the Beatrice Demonstrator project. Passive acoustic monitoring at this site in 2005, 2006 and 2007 showed that porpoises continued to use the area during the construction period, although a reduction in detection rates suggested that animals may have responded to disturbance from the turbine installation work (Thompson et al. 2010).

Together, these studies highlight that there are likely to be context specific behavioural responses by porpoises to piling noise, with animals being less likely to leave, and quicker to return to, more favoured areas. However, none of these studies were able to adequately assess the distance at which responses may occur, largely due to the difficulty of identifying suitable control sites. Recognising this problem, Thompson et al (2010) suggested that gradient designs should provide better data on variation in responses in relation to different noise levels. As described above, Technical Appendix 7.3 B: Seal Assessment Framework describes how published data from Brandt et al.'s (2011) studies at Horns Rev II were re-analysed in this way to provide a behavioural response curve for this assessment. Additional data will be forthcoming from a 2011 study of responses of porpoises to seismic survey noise in the Moray Firth, and planned work surrounding the installation of the MORL met mast.

The responses by bottlenose dolphins to piling noise have not been studied. A review of available data on behavioural responses of both porpoises and bottlenose dolphins is presented in Technical Appendix 7.3 D. Both species have positive relationships between received sound level and the level of behavioural response, but bottlenose dolphins appear to be slightly less likely to exhibit responses than porpoises at any given received noise level. The modelling undertaken for this impact assessment makes the precautionary assumption, that bottlenose dolphin will respond to noise in a similar manner (using the same dose-response curve) to porpoises.

4.2.3.2 Assessment of wind farm turbine foundations – Primary assessment

The three scenarios modelled are described in Table 4.8 below (see Technical Appendix 7.3 F for model outputs):

Table 4.8: Piling locations used for the cumulative modelling scenarios within the EDA. Please refer to Figure 01 in Technical Appendix 7.3 F for visual representation.

Scenario A	One piling vessel to build all three schemes. The vessel would remain within the Moray Firth for up to five years, building each wind farm in succession (build duration 2016-2020). Modelling based on a 2.5 m diameter pile at location 1, due to it being closest to the inner Firth.
Scenario B	Two piling vessels to build all three schemes. For this scenario, the build programme would be envisaged to take up to three years (build duration 2016-2018). It is likely that the vessel spread at any one time would be relatively small. However, for the purposes of this assessment, worst case, the modelled locations have been chosen to reflect the largest vessel spread possible, and so cumulative noise extent. Modelling based on a 2.5 m diameter pile at locations 1 and 5.
Scenario C	Six piling vessels to build all three schemes (two vessels within each site) within a two year construction phase (build duration 2016-2017). While six piling vessels are unlikely to require a full two year continuous construction period, there may be some time within this period in which all six vessels would be on site and operational together. Modelling based on a 2.5 m diameter pile at locations 1, 2, 3, 4, 5 and 6.

Full details of the modelling process are provided within the Section 4.2 of this report in conjunction with Technical Appendix 7.3 B: Seal Assessment Framework and Technical Appendix 3.6 A: Underwater noise. Visual outputs from the models can be found in Technical Appendix 7.3 F. The information from this process was then used to predict the number of individuals which would suffer PTS or be displaced during each construction phase (two to five years). The results of this can be found in Table 4.9 below. In addition, population modelling was conducted for the harbour seal and bottlenose dolphin populations. The results of this modelling for the different scenarios outlined in Table 4.8 can be found in Figures 4.6 and 4.7 below.

Table 4.9: Predicted number of individuals impacted by piling noise in year one of construction.

Harbour seal						
	Scenario A		Scenario B		Scenario C	
	Number	%	Number	%	Number	%
PTS: 186 dB	121	10.2	198	16.7	305	25.8
Behavioural displacement: High	731	61.8	823	69.6	853	72.1
Behavioural displacement: Best fit	522	44.1	629	66	667	56.4
Behavioural displacement: Low	42	3.5	66	5.6	92	7.7
Grey seal						
	Scenario A		Scenario B		Scenario C	
	Number	%	Number	%	Number	%
PTS: 186 dB	170	5.4	301	9.5	478	15.1
Behavioural displacement: High	1159	32.2	1656	46	1753	48.7
Behavioural displacement: Best fit	739	20.5	1184	32.9	1285	35.7
Behavioural displacement: Low	45	1.3	94	2.6	123	3.4
Harbour porpoise						

	Scenario A		**Scenario B**		**Scenario C**	
	Number	**%**	**Number**	**%**	**Number**	**%**
PTS: 198 dB	6.4	0.1	10.2	0.2	21.9	0.4
Behavioural displacement: High	4015	65.6	4056	73.7	5149	84.2
Behavioural displacement: Best fit	2933	47.9	3442	56.3	4208	68.8
Behavioural displacement: Low	263	4.3	367	6	629	10.3
Bottlenose dolphin						
	Scenario A		**Scenario B**		**Scenario C**	
	Number	**%**	**Number**	**%**	**Number**	**%**
PTS: 198 dB	0.06	<0.1	0.07	<0.1	0.12	0.1
Behavioural displacement: High	31	15.7	33	16.8	36	18.5
Behavioural displacement: Best fit	17	8.9	19	9.7	21	11
Behavioural displacement: Low	0	0.2	1	0.3	1	0.4
Minke Whale						
	Scenario A		**Scenario B**		**Scenario C**	
	Number	**%**	**Number**	**%**	**Number**	**%**

PTS: 198 dB	12.3	0.8	10.7	0.7	9.9	0.7
Behavioural displacement: High	206	14.1	218	14.9	222	15.2
Behavioural displacement: Best fit	168	11.5	185	12.7	191	13.1
Behavioural displacement: Low	20	1.4	27	1.8	34	2.3

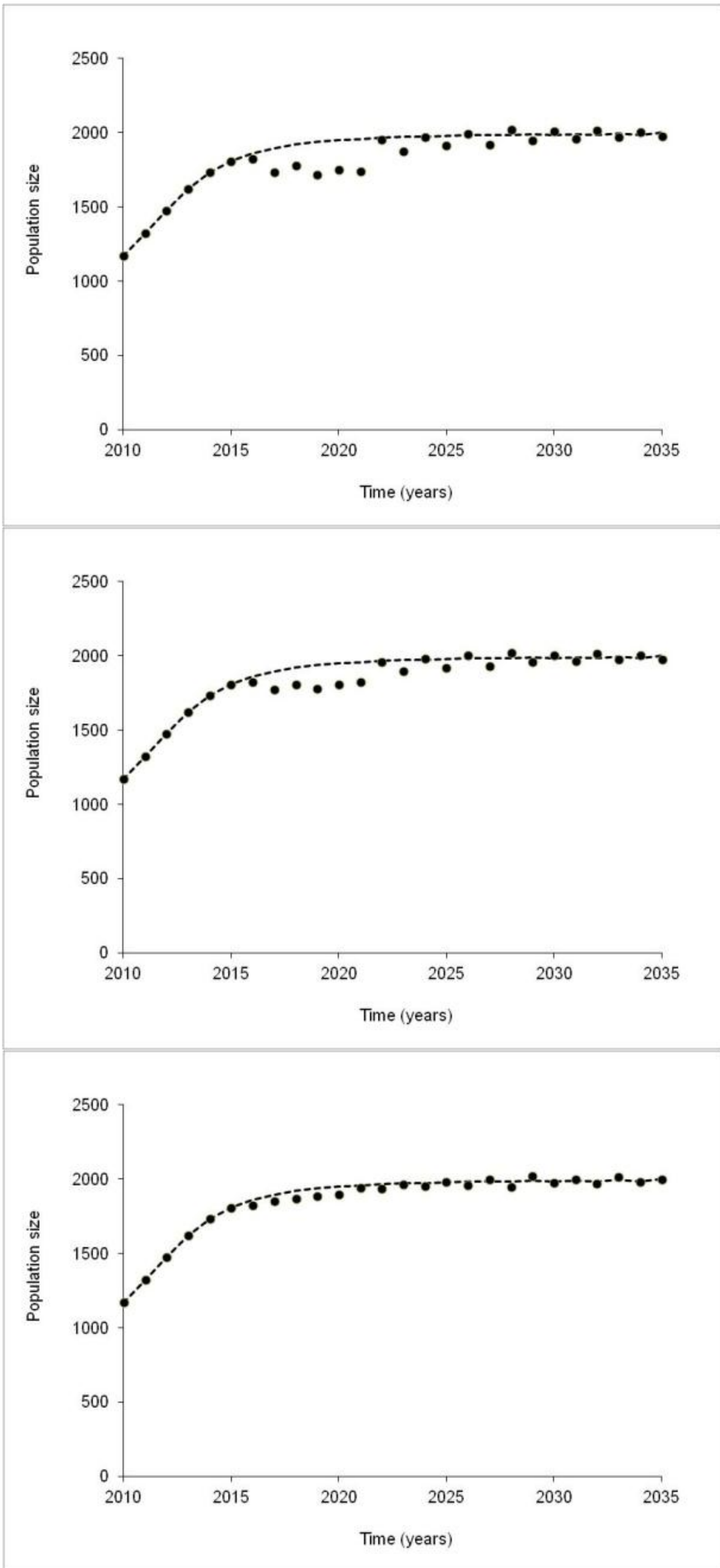


Figure 4.6a: Scenario A (one vessel for all three sites, with a construction phase of five years) – population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.

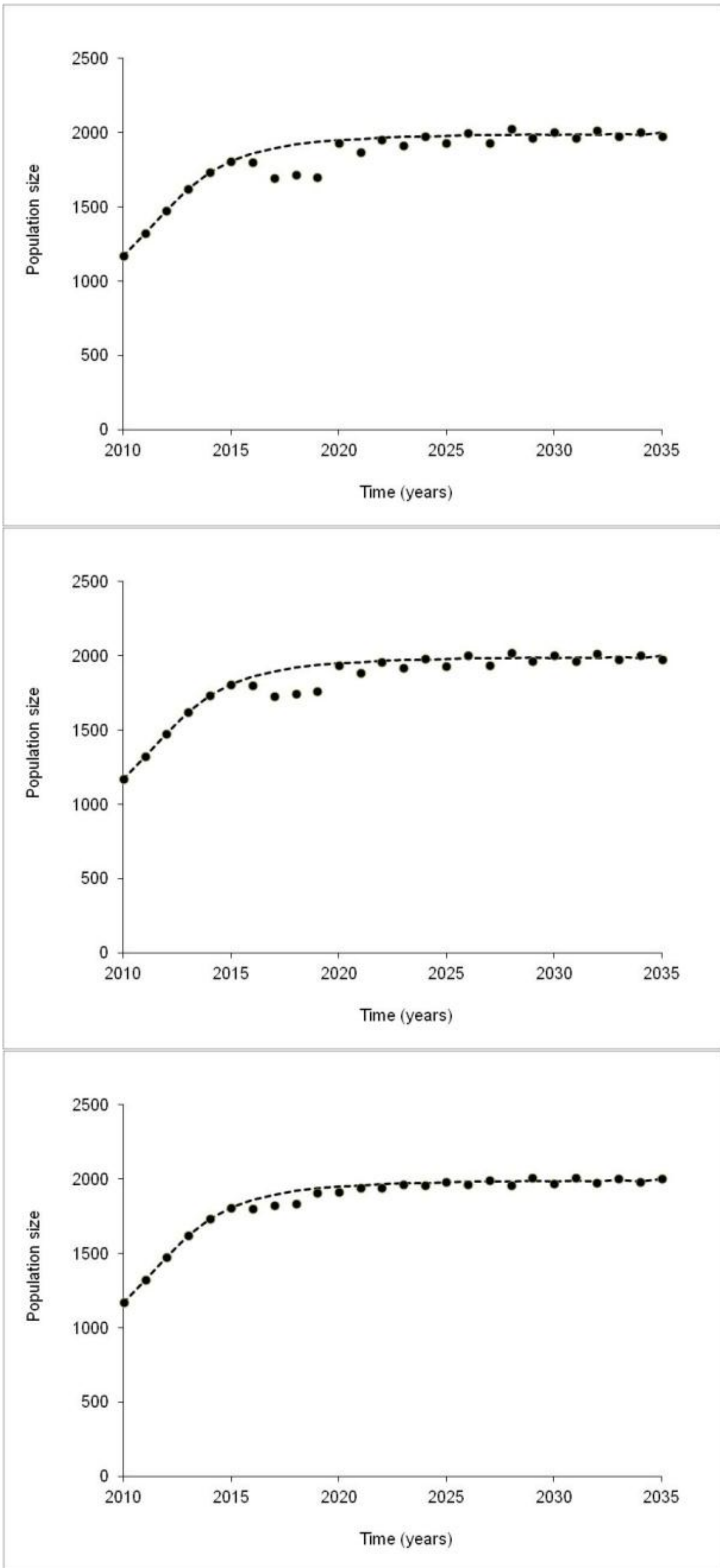


Figure 4.6b: Scenario B (two vessel for all three sites, with a construction phase of three years) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.

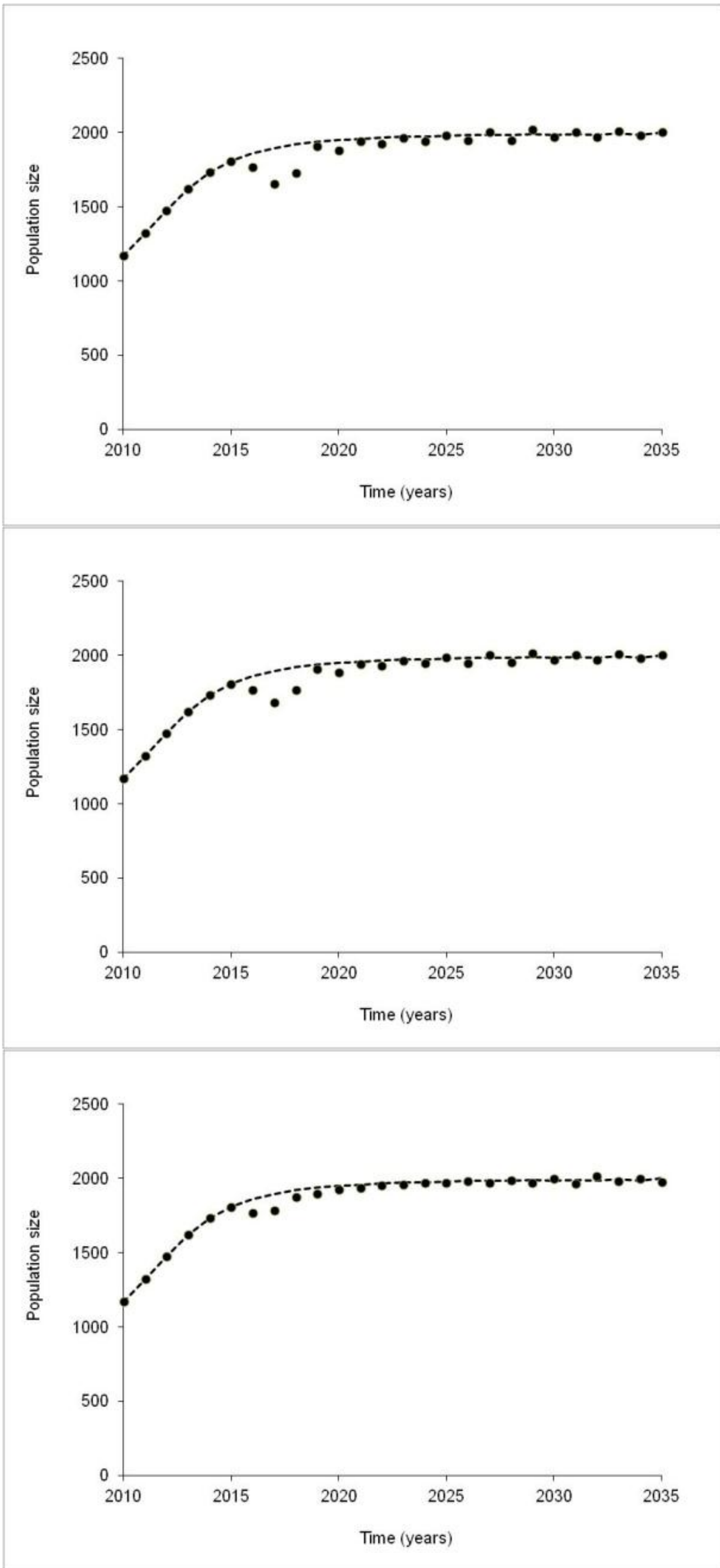
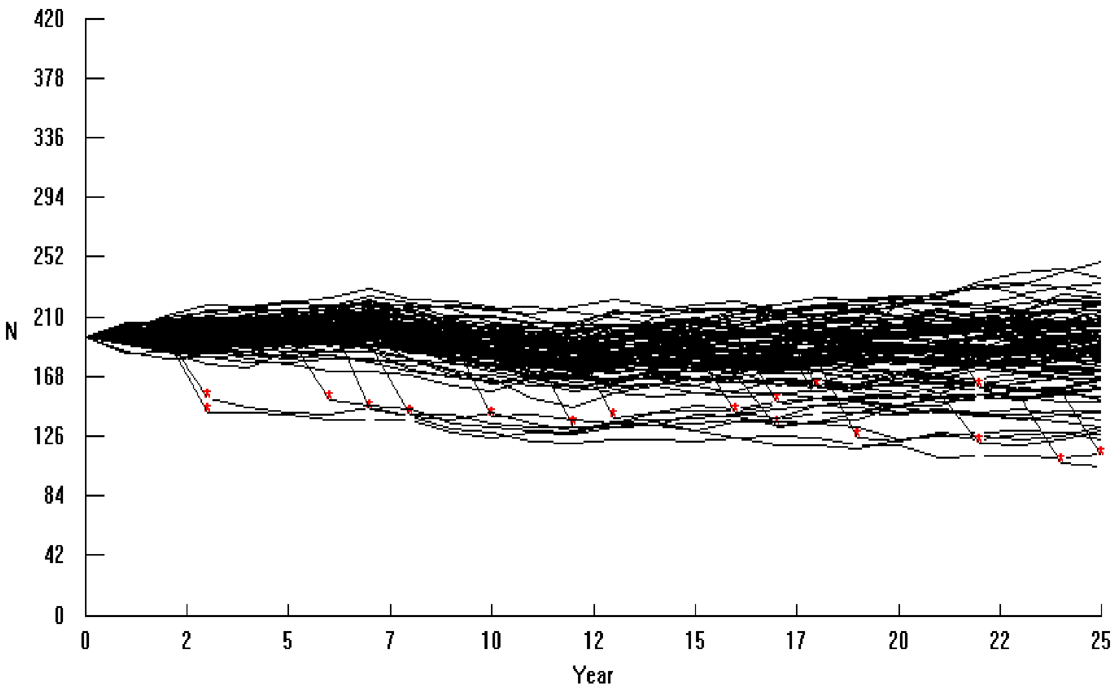


Figure4.6c: Scenario C (six vessel for all three sites, with a construction phase of two years) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.



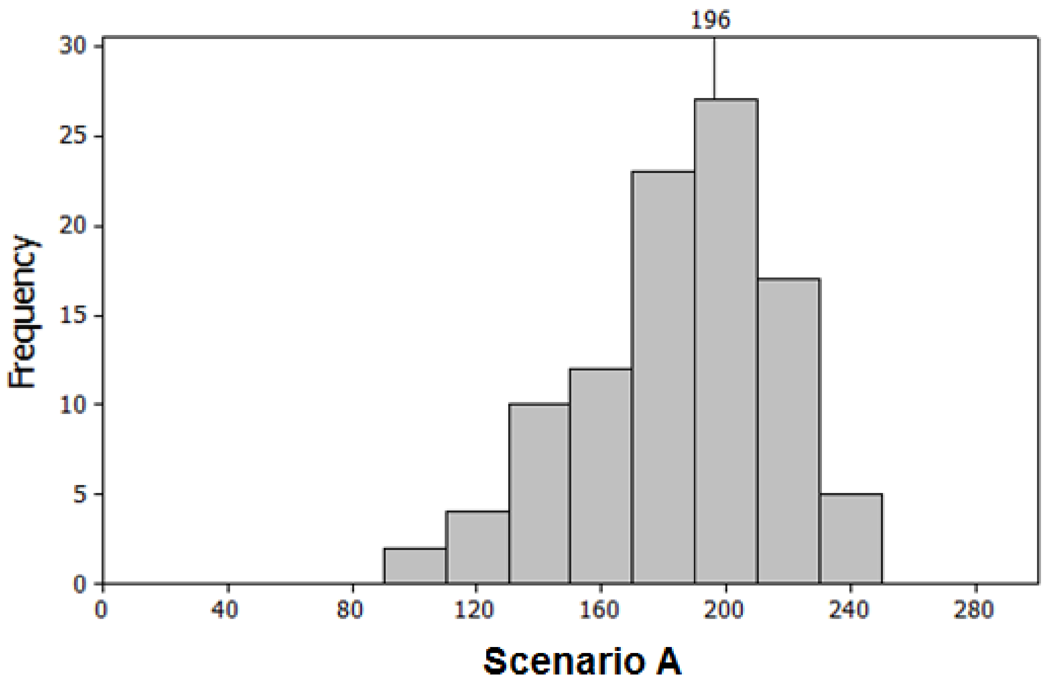
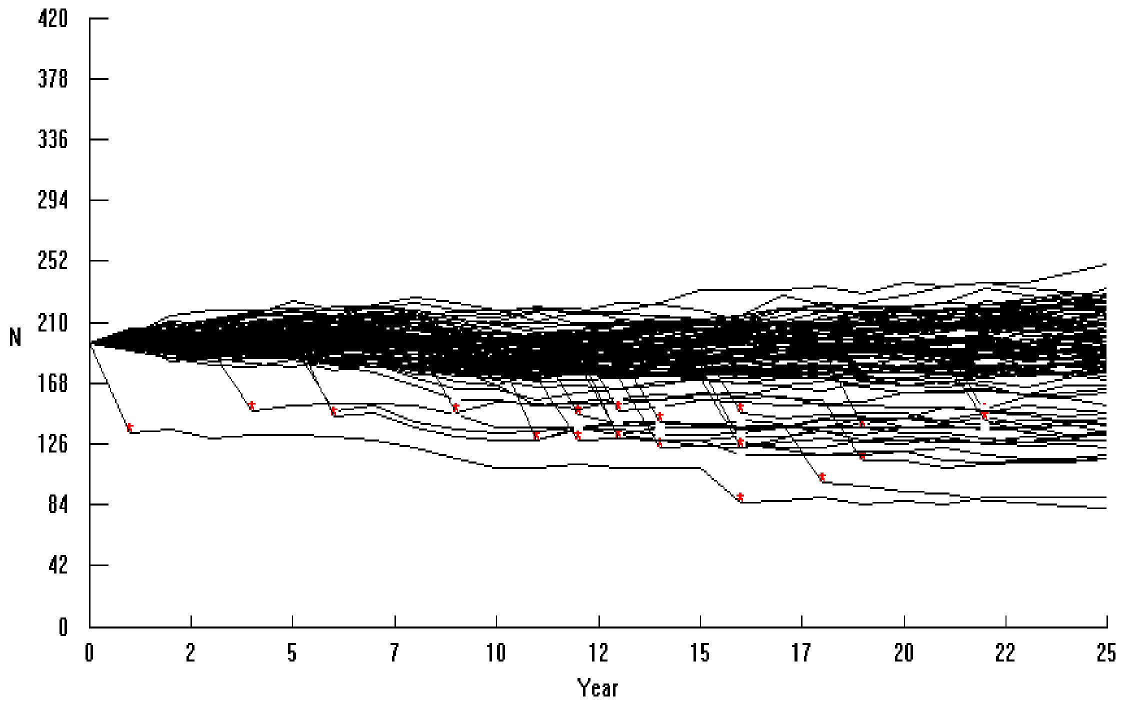


Figure 4.7a: Scenario A (one vessel for all three sites, with a construction phase of five years) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.



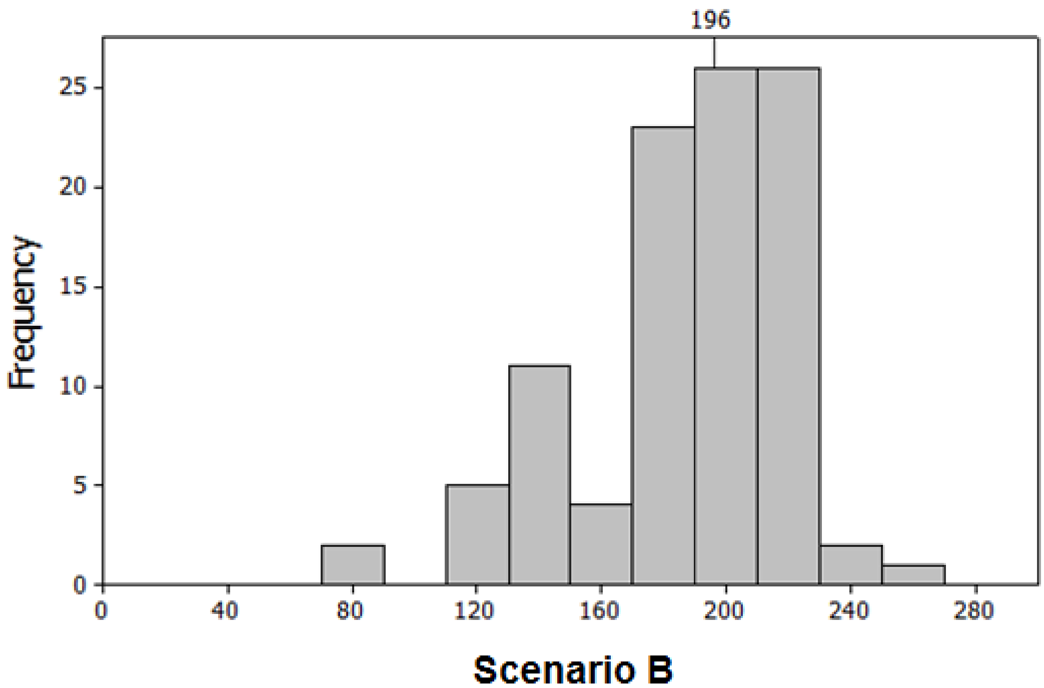
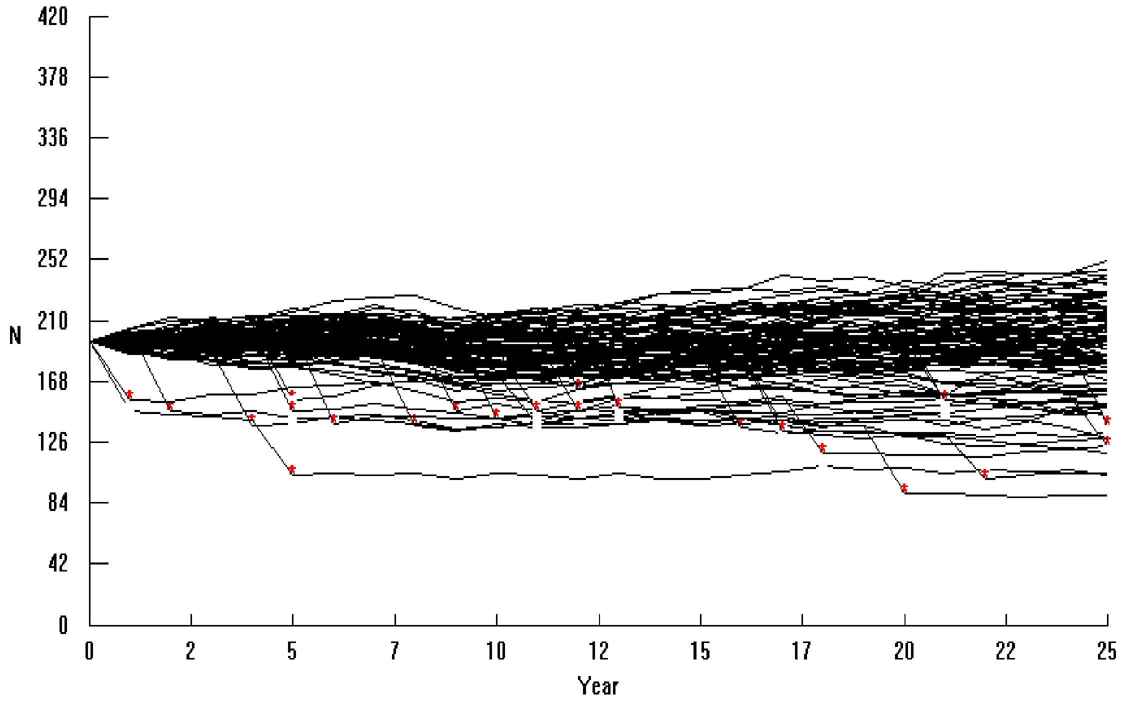


Figure 4.7b: Scenario B (two vessel for all three sites, with a construction phase of three years) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.



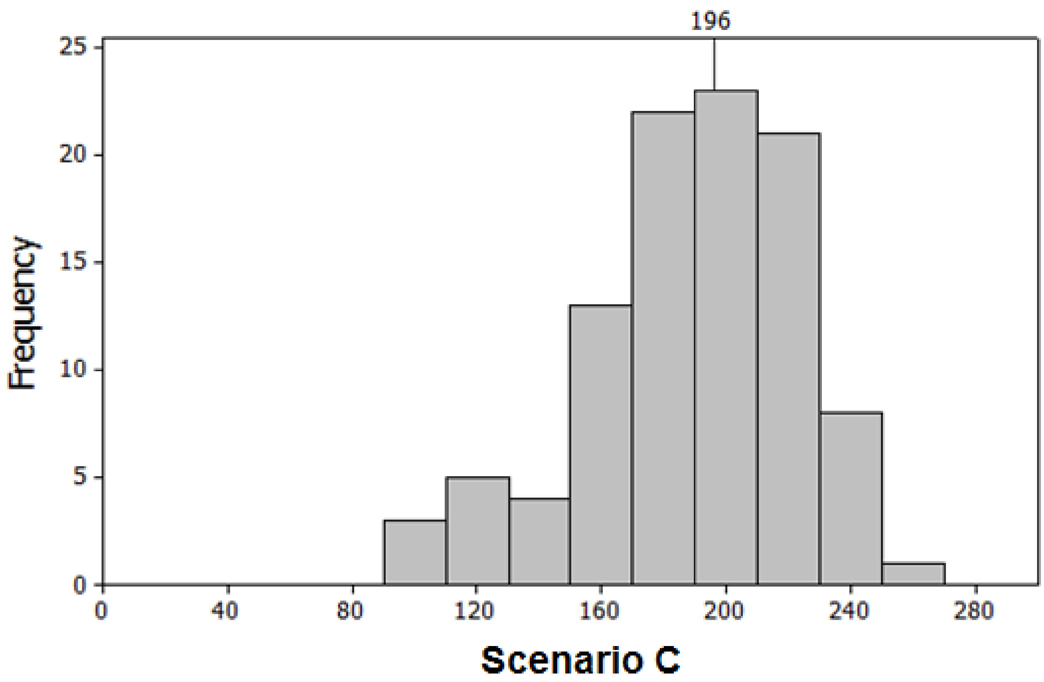


Figure 4.7c: Scenario C (six vessel for all three sites, with a construction phase of two years) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.

The modelling above indicates that while there will clearly be medium term significant impacts to the harbour seal (high magnitude, medium duration), these do not result in long term impacts on population size. Thus the overall impact is considered to be of **low magnitude** (predicted population size within 10% of that predicted as a baseline if population parameters do not change within the Moray Firth) and so **minor significance** for harbour seals

Chapter 4.4: Baseline Marine Mammals describes how the bottlenose dolphin population are found almost exclusively within the coastal strip of the Moray Firth and very rarely frequent the waters over Smith Bank. Therefore, as expected, the modelling above predicts negligible numbers of individuals exposed to levels of noise sufficient to induce PTS, and a medium magnitude level for displacement. Partial displacement has the potential to occur within the coastal corridors and associated foraging areas that link the Inner Moray Firth and Forth of Tay/Aberdeen rather than within the Moray Firth SAC. However, gaps within the piling regime are likely to be sufficient to enable animals to continue to use these areas. The population modelling undertaken (which assumes displacement from coastal foraging grounds and a similar sensitivity to noise as for harbour porpoises) indicates that there will be no long term impacts upon the population size from the modelled construction activity from all three scenarios. The overall impact is considered to be of low magnitude (predicted population size within 10% of that predicted as a baseline if population parameters to not change within the Moray Firth) and so **minor significance**.

A similar approach to the short, medium and long term impact upon grey seals, harbour porpoises and minke whales has been adopted; a lack of appropriate data means that population modelling has not been undertaken for these species.

Many of the grey seals observed within the Moray Firth are believed to have originated from breeding and haul-out sites outside the area (see Technical Appendix 4.4 A: Baseline marine mammals). While the modelling undertaken has predicted low (Scenario A and B) to medium (Scenario C) magnitude number of grey seals exposed to noise levels sufficient to induce PTS onset, these numbers are considered highly conservative and likely to represent a significant over-estimation (see Table 4.7 above, in particular assumption 9). Given the results of population modelling for harbour seals in the Moray Firth, any impact upon the larger and increasing grey seal population is unlikely to have a significant long-term effect at the population level. While the impacts of behavioural displacement on grey seals within the Moray Firth are considered to be of short and medium term **major significance**, given that most grey seals are not tied to specific breeding or feeding grounds within the Moray Firth it is suggested that the long term impact on this species at the population level will be of **minor significance**.

Both harbour porpoise and minke whales have widespread distributions and do not appear to be tied to specific feeding or breeding grounds. The modelled numbers of individuals of both species predicted to experience PTS are of low magnitude, while the disturbance impacts from piling within the wind farm site on individuals within the Moray Firth are considered of short and medium term **major significance**. Given the wide distribution and relative abundance of both species, the long term impacts at the population level will be **minor significance**.

4.2.3.3 Assessment of wind farm turbine foundations – Secondary assessment

As detailed in the Rochdale Envelope (ES Chapter 2.2 Project Description), the three sites combined (Telford, Stevenson and MacColl) will contain a total of between 216 and 339 turbines, depending on the final turbine models chosen. Details of the number of turbines within each site can be found in Table 4.10 below. It is not known at this time which of the three sites will be developed first (as site 1).

Table 4.10: The proposed number of turbines within each of the three developments (Telford, Stevenson and MacColl).

	Site 1	Site 2	Site 3
Turbine rating	3.6 to 7 or 8	5 to 7 or 8	5 to 7 or 8
Number of turbines	139 - 72	100 - 72	100 - 72

All models were undertaken based on the use of the worst case scenario of a 2.5 m diameter pile in substrate type 3 with two piles installed within a 24 hour period. Details of pile locations can be found in Table 4.11 below in conjunction with Figure 01 in Technical Appendix 7.3 F.

Table 4.11: Locations used for modelling scenarios. Please refer to Figure 01 in Technical Appendix 7.3 F for visual representation.

Wind farm site	Pile location (as shown in Figure 01 of Technical Appendix 7.3 F)
Scenario 1: MacColl	1 and 2
Scenario 2: Stevenson	4 and 6
Scenario 3: Telford	3a and 5a

Results for the number of individuals predicted to be displaced or develop PTS as a result of piling within each of the proposed wind farms in the first year of construction can be found in Table 4.9. These modelling scenarios assume two piling vessels operating simultaneously, and that animals will not return to favoured habitat in between piling events so are displaced for the full construction phase. All three sites are modelled to be built out separately (i.e. not at the same time).

Table 4.12: Number of individuals, and proportion of population (%), predicted to develop PTS or exhibit behavioural displacement as a result of piling noise in year one of construction, two piling vessels operating simultaneously. It has been assumed that these figures equate to additional yearly effects from subsequent years.

Harbour seal						
	Scenario 1: MacColl		Scenario 2: Stevenson		Scenario 3: Telford	
	Number	%	Number	%	Number	%
PTS: 186 dB	180	15.2	172	14.5	175	14.8
Behavioural displacement: High	806	68.1	707	59.8	691	58.4
Behavioural displacement: Best fit	602	50.9	514	43.5	511	43.2
Behavioural displacement: Low	57	4.8	52	4.4	55	4.7
Grey seal						
	Scenario 1: MacColl		Scenario 2: Stevenson		Scenario 3: Telford	
	Number	%	Number	%	Number	%
PTS: 186 dB	269	8.5	243	7.7	263	8.3
Behavioural displacement: High	1463	40.7	1313	36.5	1438	40
Behavioural displacement: Best fit	988	27.5	865	24.1	991	27.5

Behavioural displacement: Low	72	2	55	1.5	70	2
Harbour porpoise						
	Scenario 1: MacColl		**Scenario 2: Stevenson**		**Scenario 3: Telford**	
	Number	**%**	**Number**	**%**	**Number**	**%**
PTS: 198 dB	10	0.2	8.9	0.2	9	0.2
Behavioural displacement: High	4537	74.7	5131	83.9	4098	67
Behavioural displacement: Best fit	3452	56.4	4171	68.2	3007	49.2
Behavioural displacement: Low	357	5.8	545	8.9	305	5
Bottlenose dolphin						
	Scenario 1: MacColl		**Scenario 2: Stevenson**		**Scenario 3: Telford**	
	Number	**%**	**Number**	**%**	**Number**	**%**
PTS: 198 dB	0.08	<0.1	0.06	<0.1	0.06	<0.1
Behavioural displacement: High	34	17.5	25	12.7	23	11.7
Behavioural displacement: Best fit	20	10.1	14	7.2	13	6.6
Behavioural displacement: Low	1	0.3	0	0.2	0	0.2
Minke whale						

	Scenario 1: MacColl		Scenario 2: Stevenson		Scenario 3: Telford	
	Number	**%**	**Number**	**%**	**Number**	**%**
PTS: 198 dB	8.9	0.6	9.6	0.7	9.2	0.6
Behavioural displacement: High	218	14.9	208	14.2	209	14.3
Behavioural displacement: Best fit	185	12.7	171	11.7	174	11.9
Behavioural displacement: Low	27	1.9	22	1.5	24	1.6

The outputs from the population modelling for harbour seal and bottlenose dolphin based on piling within each of the wind farm developments can be found in Figures 4.8 and 4.9.

Figure 4.8(a-c) illustrates the matrix model outputs for harbour seal based on the upper, best fit and lower predictions for each scenario. Figure 4.9 (a-c) illustrates the population size graphs for bottlenose dolphins generated by Vortex for each scenario, with a histogram showing the frequency distribution of final population estimates for each run after 25 years.

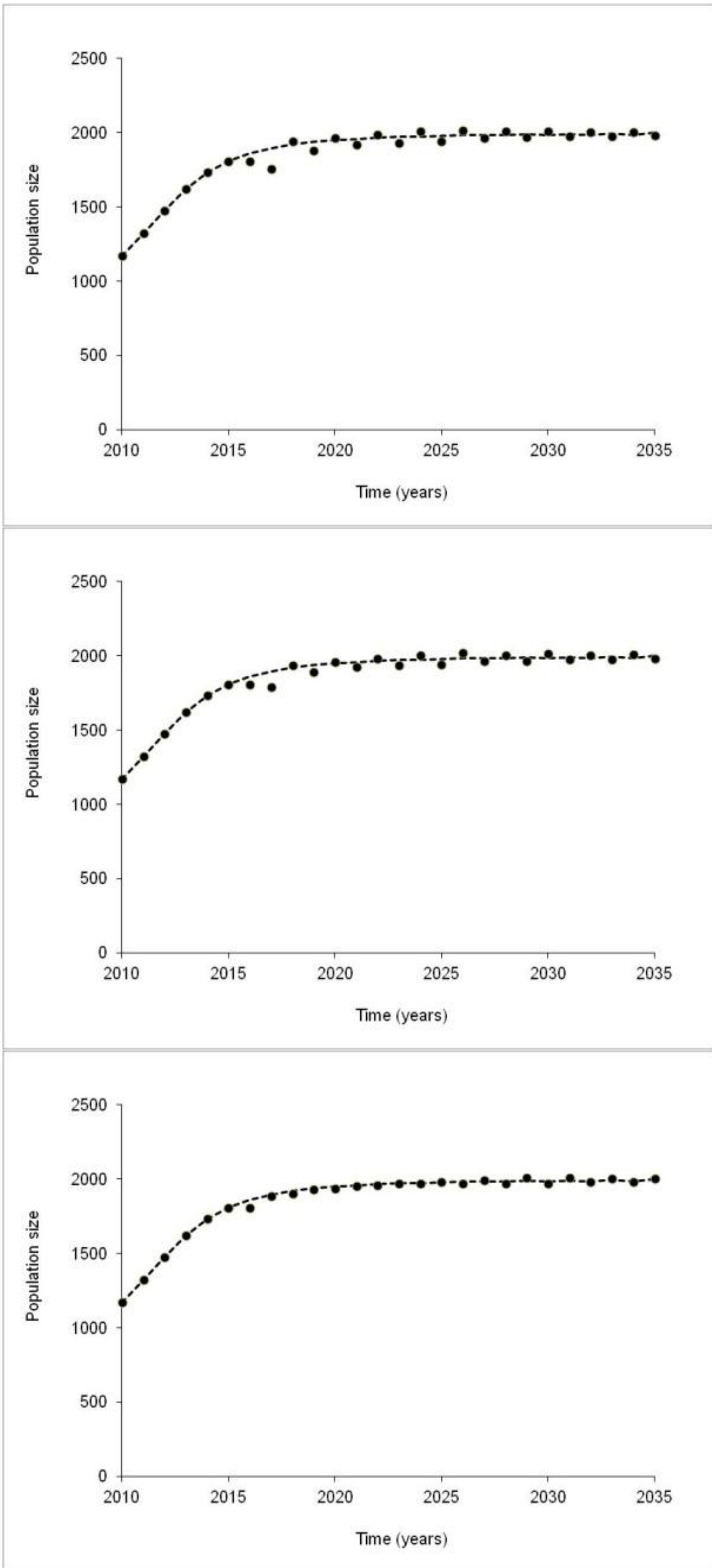


Figure 4.8a: Scenario 1 (two piling vessels at MacColl) – population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction for behavioural displacement.

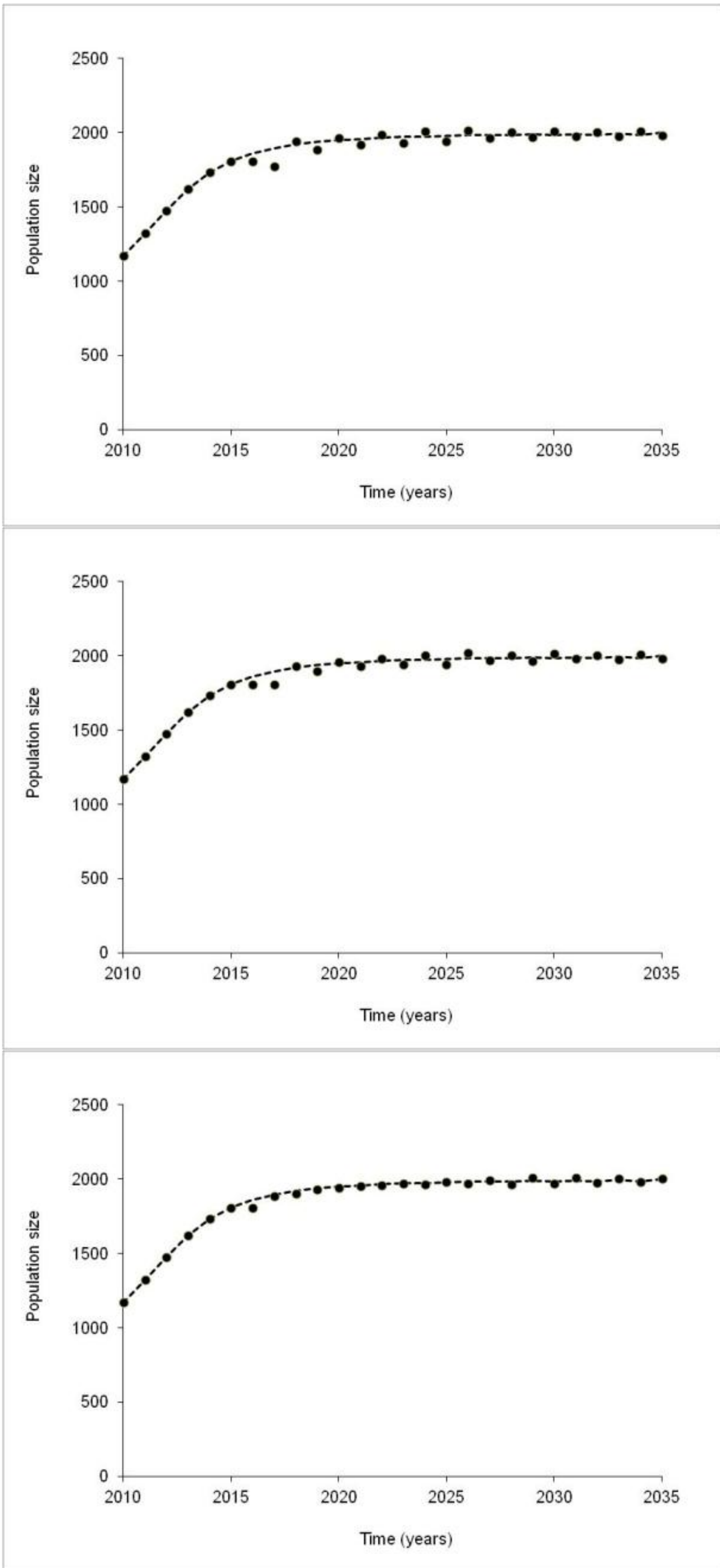


Figure 4.8b: Scenario 2 (two piling vessels at Stevenson) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction for behavioural displacement.

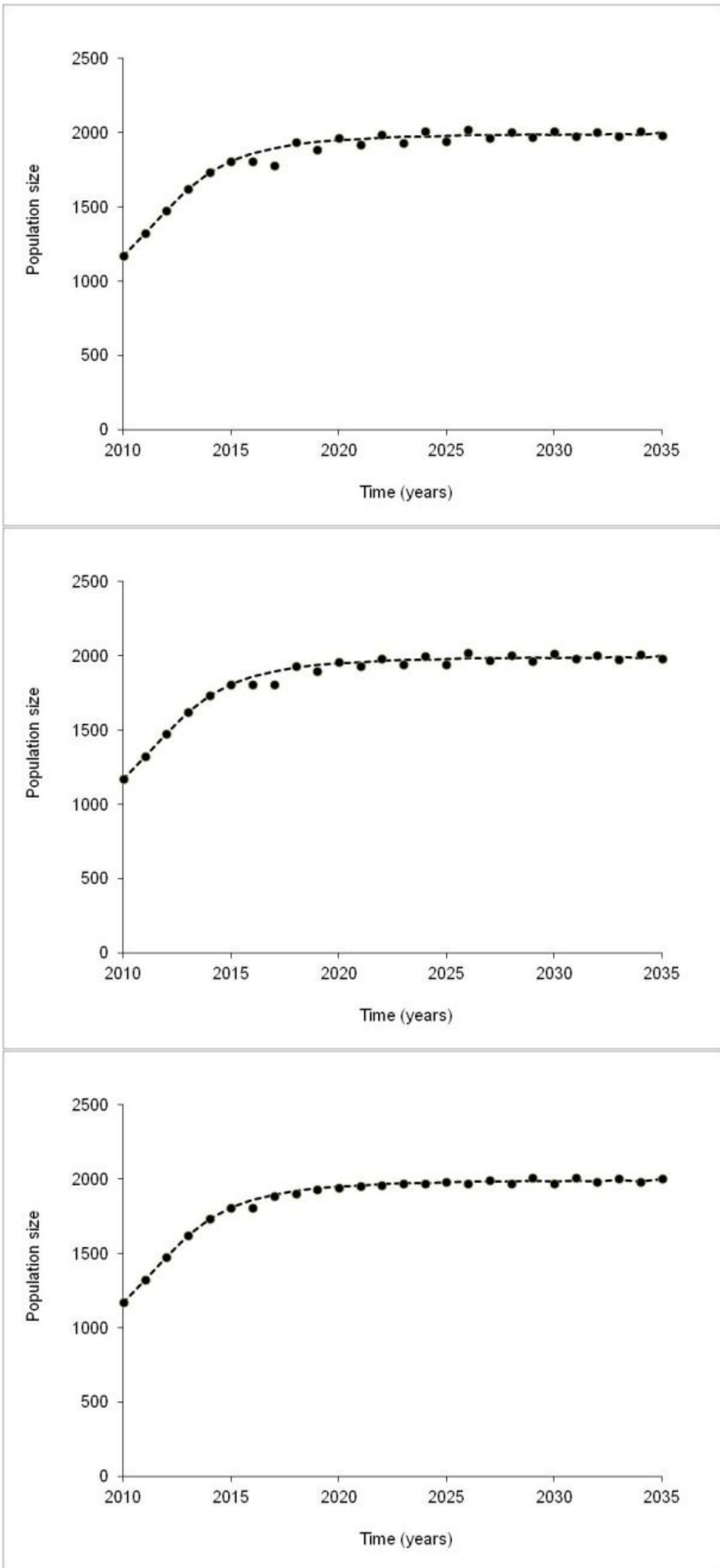
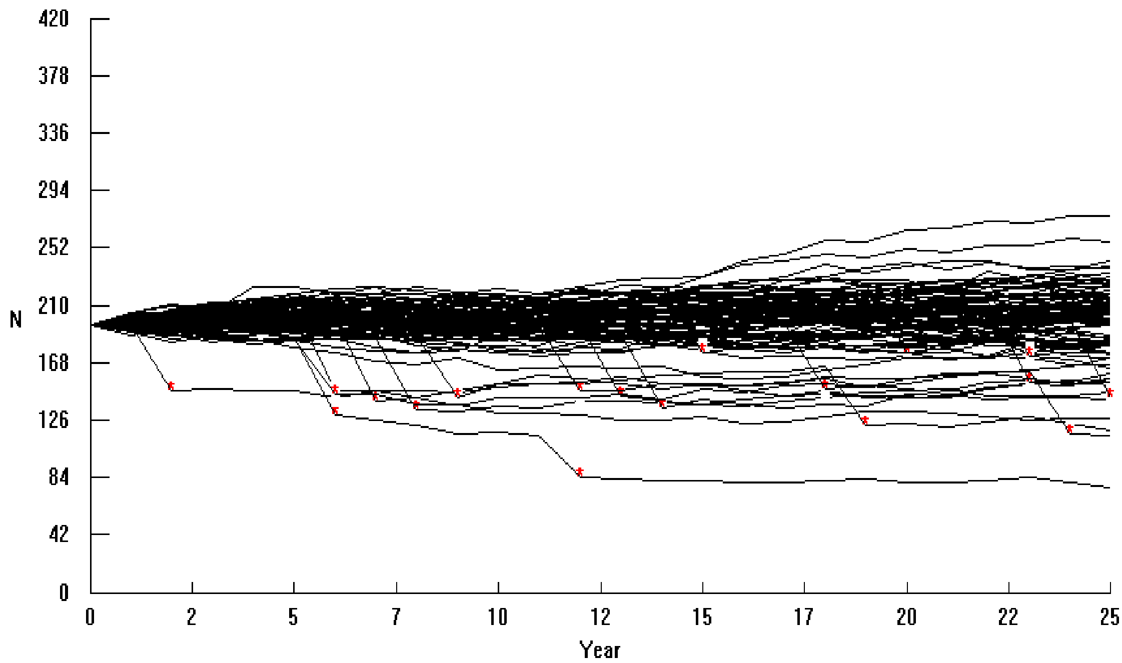


Figure 4.8c: Scenario 3 (two piling vessels at Telford) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom t: upper, best fit and lower prediction for behavioural displacement.



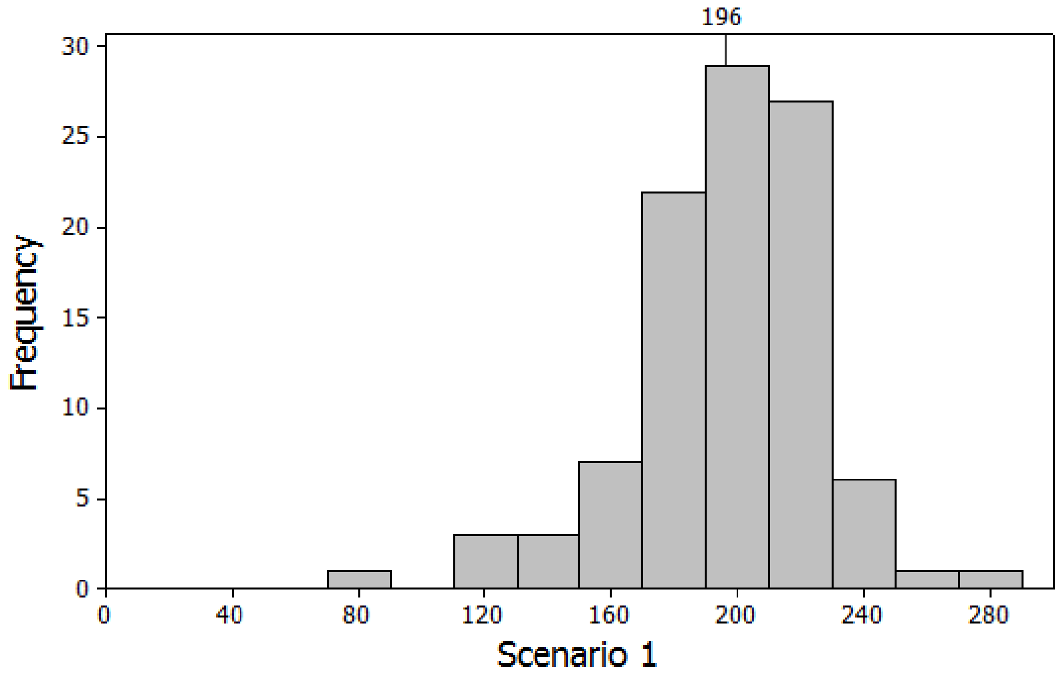
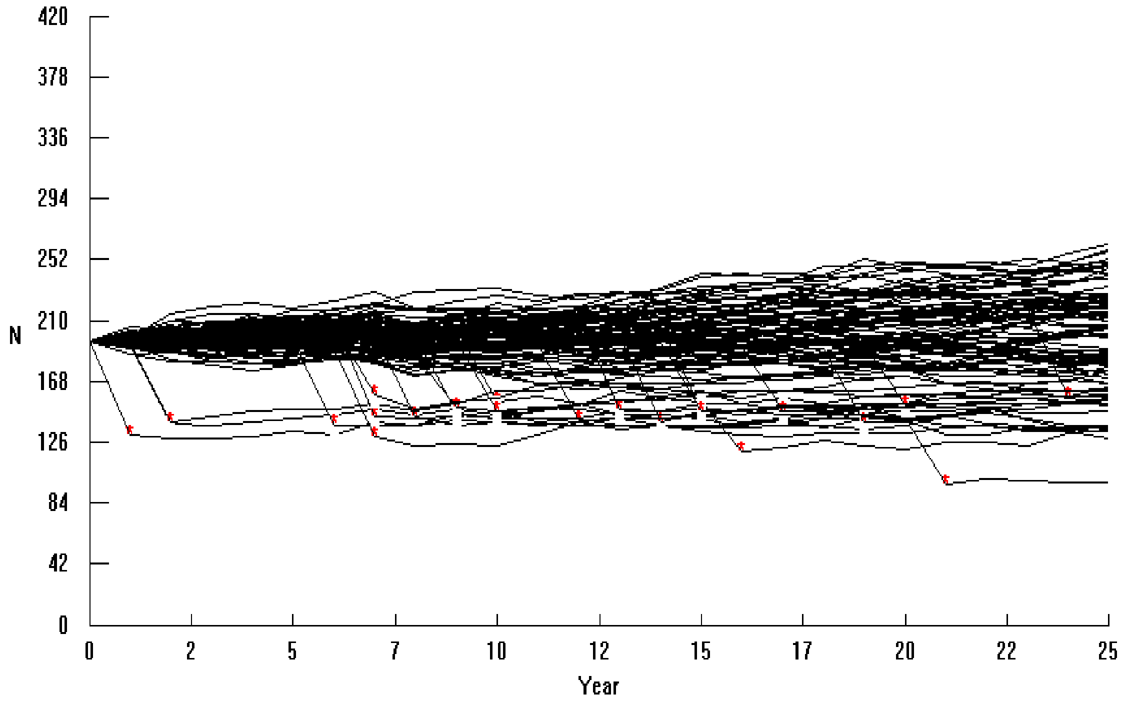


Figure 4.9a: Scenario 1 (two piling vessels at MacColl) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size over time graph; lower = frequency distribution of predicted population size after 25 years.



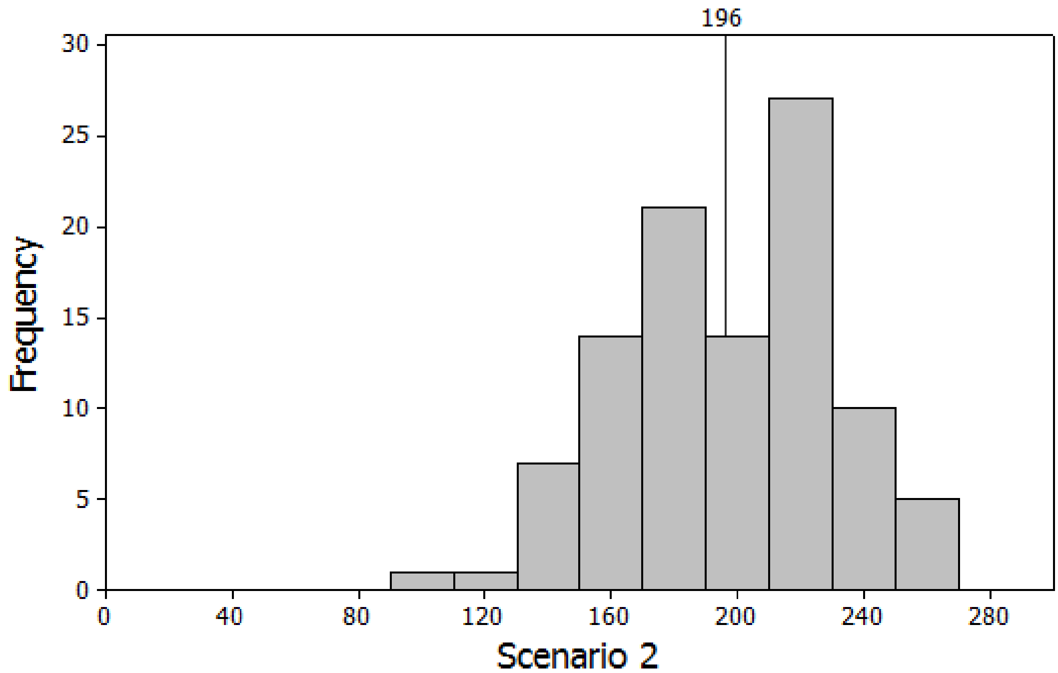
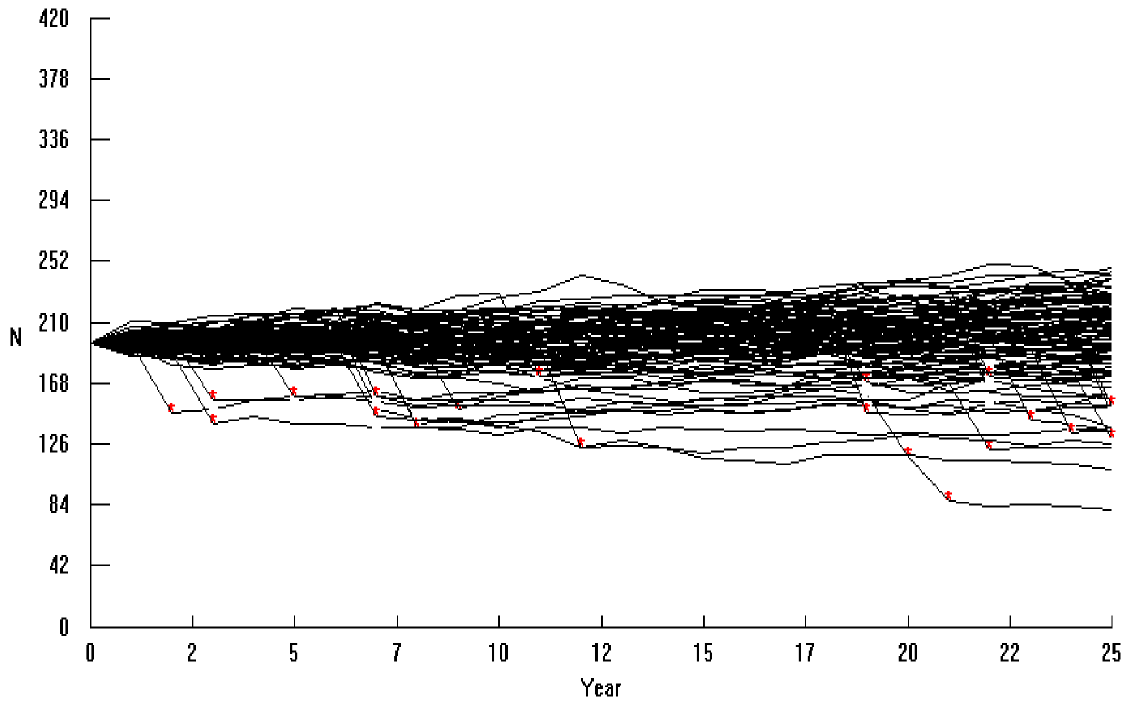


Figure 4.9b: Scenario 2 (two piling vessels at Stevenson) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size over time graph; lower = frequency distribution of predicted population size after 25 years.



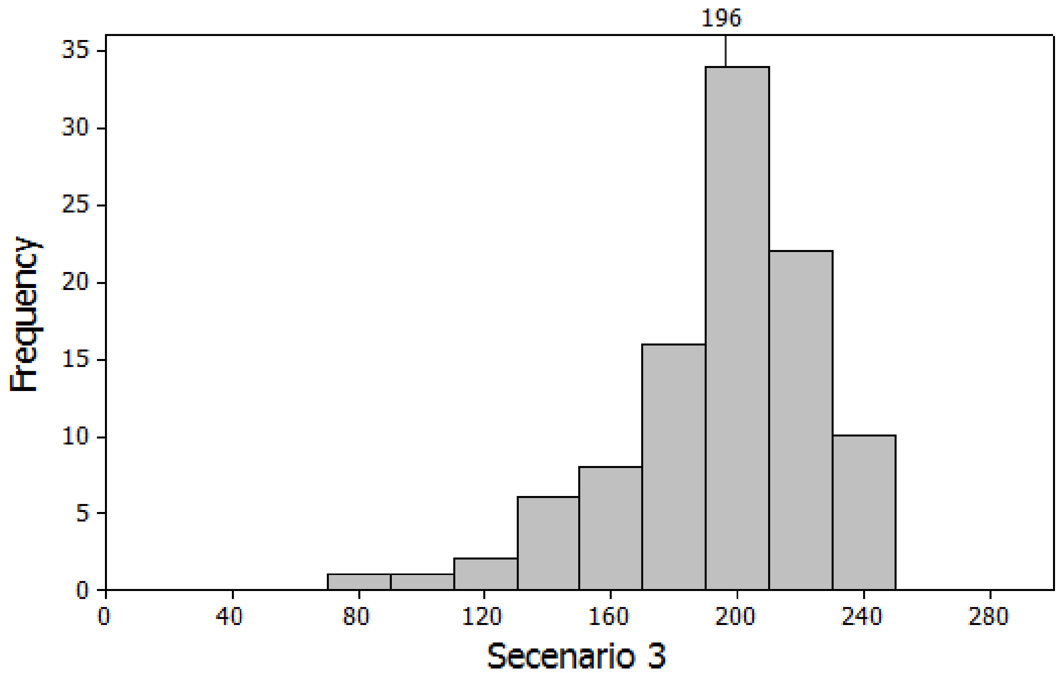


Figure 4.9c: Scenario 3 (two piling vessels at Telford) – population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 196 dB SAFESIMM model outputs. Upper = population size over time graph; lower = frequency distribution of predicted population size after 25 years.

The modelling presented above indicates that there will be medium term high significance impacts for harbour seal (high magnitude, medium duration) and medium term medium significance impacts for bottlenose dolphin (medium magnitude, medium duration) populations. However, these impacts are not (a) long term and (b) significantly different from each other with regards to site specific characterisation.

It can be seen from the maps presented in Technical Appendix 7.3 F that the dB_{ht} contours for harbour seals are similar for all three scenarios. This is also true when considering the dB_{ht} contours for bottlenose dolphins, as also shown in Technical Appendix 7.3 F. Table 4.12 above provides similar figures for displacement and potential PTS onset experienced across all three scenarios. Thus the impact of each site is considered to be of long term **low magnitude** (predicted population size within 10% of that predicted as a baseline if population parameters do not change within the Moray Firth) and so **minor significance** in the long term for both harbour seals and bottlenose dolphins.

This lack of difference is also apparent in the impact upon grey seals, harbour porpoise and minke whale, although population modelling has not been undertaken for these species.

4.2.3.4 Assessment of meteorological mast

A Marine License has been awarded for the installation of an offshore meteorological mast (met-mast) to be installed during 2012. The installation of a second mast is planned at some stage through the offshore wind farm construction period. There are three types of foundation that could be used:

- Single monopole with a diameter of 4.5 m;
- Steel jacket substructure with pin-piles similar to those used for wind turbines;
- Gravity base foundation.

The proposed method with the greatest impact is predicted to be the use of a 4.5 m monopile. Given that this will involve the installation of a single pile and therefore be of short impact duration, the full impact modelling described for turbine foundation installation above was not conducted for this single installation.

The SPEAR model described in Section 4.1 was repeated using a 4.5 m diameter pile. The predicted output from this model can be found in Table 4.13, with the results from a 3 m pile (substation foundation) included for comparison. Visual representation of the impact radii for using the dB_{ht} (*species*) and SEL criteria can be found in Technical Appendix 7.3 F. It should be noted that the SPEAR modelling process includes full blow energies only and does not incorporate a soft start.

Table 4.13: The predicted behavioural impact distance (in meters) from SPEAR model on 4.5 m pile, based on a 90 dB_{ht} value.

Pile diameter	Minke whale	Bottlenose dolphin	Harbour porpoise	Harbour seal
4.5 m pile	13, 000 m	8,400 m	13,000 m	5,900 m
3 m pile	12, 000 m	7,700 m	12,000 m	5,400 m

Modelling undertaken for the installation of the 3 m OSP piles suggests the impacts of behavioural avoidance will be of high significance for the duration of the installation with low long-term impacts. The SPEAR modelling above suggests that behavioural avoidance associated with the installation of a 4.5 m pile taken in isolation will occur at a slightly greater distance from the pile than that associated with a 3 m pile although the disturbance will occur over a much shorter duration (i.e. a couple of days). It is therefore considered that the effects of piling a 4.5 m pile will be of **major significance** but for a **short duration** for all marine mammal species, and thus be of overall **negligible significance**.

Given the level of construction that will be occurring simultaneously to the installation of this second met-mast, it is suggested that the impacts of this single construction activity will be incorporated with those occurring around it, and it is considered that the additional impacts resulting from this single pile will not be distinguishable from the already high levels of anthropogenic noise present in the Moray Firth during the wind farm construction phase.

4.2.3.5 Assessment of substation foundations

In addition to the piling scenarios described above, potential piling operations associated with the installation of transmission infrastructure were considered.

For the offshore connection, the proposed infrastructure will include up to six AC collector offshore substation platforms (OSPs) and two AC/DC convertor OSPs. A number of foundation types are currently under consideration including jackets and jack-ups with pin piles, which would therefore require piling (see ES Chapter 2.2: Project Description for more details).

The proposed diameter for these piles is 3 m. In order to assess the impact of piling these foundations, the assessment framework described above was repeated assuming piling occurred at Location 2 using a 3 m pile (see Figure 01 in Technical Appendix 7.3 F). Outputs from the noise modelling can be found in Technical Appendix 7.3 F and the predicted number of individuals impacted in Table 4.14 below.

Results from the harbour seal population modelling can be found in Figures 4.10. This modelling assumes that the construction activity would be spread over the construction period of the wind farms, with a start towards the end of 2015.

Table 4.14: Predicted number of individuals impacted by piling noise associated with OSPs in year one of construction.

Harbour seal		
	Number	**%**
PTS: 186 dB	125	10.6
Behavioural displacement: High	650	54.9
Behavioural displacement: Best fit	459	38.8
Behavioural displacement: Low	36	3
Grey seal		
	Number	**%**
PTS: 186 dB	203	6.2
Behavioural displacement: High	1250	34.7
Behavioural displacement: Best fit	823	22.9
Behavioural displacement: Low	50	1.4
Harbour porpoise		
	Number	**%**
PTS: 198 dB	6.2	0.1
Behavioural displacement: High	4040	66.1
Behavioural displacement: Best fit	2930	47.9

Behavioural displacement: Low	241	3.9
Bottlenose dolphin		
	Number	**%**
PTS: 198 dB	0.05	<0.1
Behavioural displacement: High	28	14.3
Behavioural displacement: Best fit	16	8.1
Behavioural displacement: Low	0	0.2
Minke whale		
	Number	**%**
PTS: 198 dB	28.1	1.9
Behavioural displacement: High	208	14.2
Behavioural displacement: Best fit	173	11.8
Behavioural displacement: Low	22	1.5

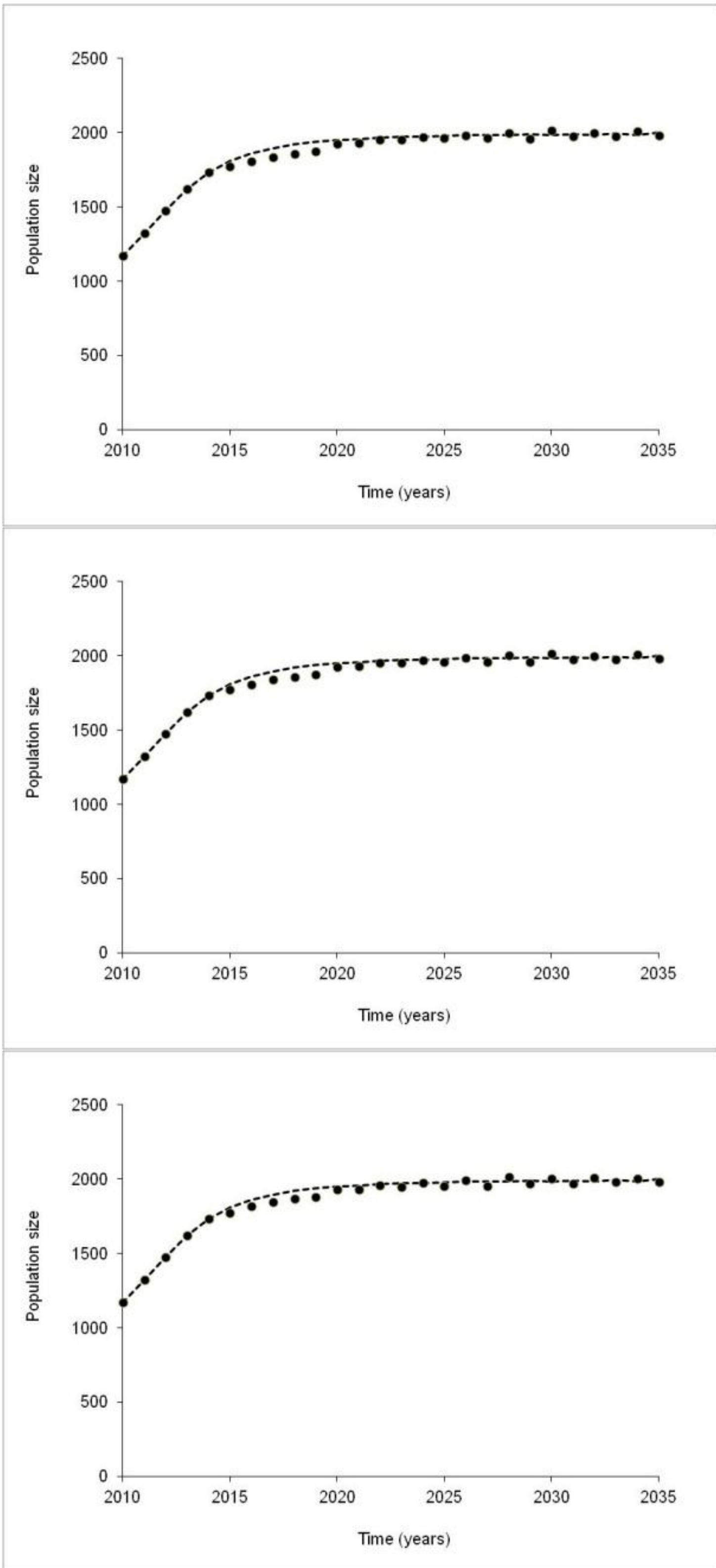


Figure 4.10: Population modelling for the harbour seal population in the Moray Firth for 3m pin piles (OSP's). Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.

The modelling above indicates that while there will clearly be significant displacement effects to the harbour seal during the piling for the OSPs (high magnitude, low to medium duration each year), these effects at a population scale do not extend to long term effects on population size. The model predicts that the population will recover to projected baseline size once piling has ceased. Thus the overall effect is considered to be of **low magnitude** (predicted population size within 10% of that predicted as a baseline if population parameters do not change within the Moray Firth) and so **minor significance**.

Following review of the harbour seal population modelling outputs for the OfTI and the bottlenose dolphin population modelling for the generating station (see Section 4.2.3.2 above), given the short time period that would be required to install the pin piles for these foundations (i.e. up to a week per platform, and a month per year if multiple platforms are installed during one year) during which other piling on site is likely to be occurring, it was considered these activities would not affect the long-term viability of the bottlenose dolphin population. Population modelling for bottlenose dolphin was therefore not undertaken for this assessment. Impacts on bottlenose dolphins are predicted to be of **medium magnitude**, for **short to medium durations** and thus of **minor significance** in the long term.

Many of the grey seals observed within the Moray Firth are believed to have originated from haul-out sites outside of the area (see Technical Appendix 4.4 A: Baseline marine mammals). While the effects of behavioural displacement on grey seals within the Moray Firth during OSP related piling are considered to be of **high magnitude**, the effect is of **short to medium duration**. Given that grey seals do not appear to be tied to specific breeding or feeding grounds within the Moray Firth it is suggested that the long term effect on this species at the population level will be of **minor significance**.

Both harbour porpoise and minke whales exhibit generalised distributions and do not appear to be tied to specific feeding or breeding grounds. The effects from piling OSP foundations on individuals within the Moray Firth are considered of **high** (harbour porpoise) and **medium** (minke whale) **magnitude.** However, given the **short to medium duration** of this displacement and the generalised distribution and relative abundance of both species, the long effects at the population level will be of **minor significance**.

The above described predictions are based on the assumption that substation foundation installation will occur at a separate time to turbine installation. In reality, the majority of the substations are likely to be installed within the same time frame to the wind turbines and it is suggested that any effects from the installation of these piles will be incorporated into the effects of piling turbine foundations, without increasing the predicted effects of either event.

4.3 Increased vessel use: Collision risk and use of ducted propellers

4.3.1 Prediction of impact

Ship strikes are known to be a cause of mortality for marine mammals worldwide (Pace *et al*, 2006; Laist *et al,* 2001). Detailed levels of occurrence are unknown (Laist *et al,* 2001) since a large proportion are thought to go unrecorded (David, 2006). In one review of strandings data, it was found ship strikes accounted for between 12 and 47% of the recovered carcasses (Carter, 2007). In addition to physical injury, behavioural responses to vessel traffic may also occur although these are most likely a response to engine noise and are therefore discussed further in ES Section 7.6: Underwater Noise.

In recent years, concern has been raised by Statutory Nature Conservation Agencies (SNCAs) on the potential impact upon seals from vessels fitted with ducted propellers. Since 2008, a number of carcasses have been found in south-east Scotland, the north Norfolk coast and around Strangford Lough (Northern Ireland), with a characteristic single smooth edge cut spirally the length of the body, (Thompson *et al*., 2010b). In all cases examined, the wound was fatal. It was concluded that these injuries were consistent with the animals being pulled through a ducted propeller common to a wide range of vessels including tugs, self-propelled barges, rigs, offshore support vessels and research boats (Thompson *et al*., 2010b).

4.3.2 Characterisation of potential impact

Several options are being considered for transferring equipment and personnel to the construction zone (see ES Chapter 2.2: Project description) including:

- The establishment of an onshore base at a local port or harbour (yet to be decided) from which equipment/personnel can transfer by boat to the site;
- The establishment of an offshore floating base moored within a site, from which smaller craft can be launched.

The precise nature of the vessels to be used is still to be determined but there are a number of options (see ES Chapter 2.2: Project description) including: jack-up platforms, barges, dredgers, cable laying vessels and tugs. An indication of the total number of transits that could occur between site and construction port can be found in Table 4.15. A likely worst case scenario for this impact assessment would be that during construction a number of vessels would be commuting between the site and shore on a daily basis and, for the purpose of this assessment, the longest potential construction period of five years is considered.

An indication of the number of days vessels will be working within the proposed sites can be found in Table 4.16. This assumes only one simultaneous operation for each activity and that all activities are smoothed over the entire year. In reality, multiple activities may occur simultaneously, which would shorten the overall duration in vessel activity but may cause peaks during certain time periods. The impacts of construction at more than one site simultaneously can be found in Section 7.1.2 of this report.

Table 4.15: Indication of vessel movements between construction port and site (and return) during the five year construction period (2015-2020)[7].

Foundation piling	Sub-structure	WTG installation and commissioning	Array cable installation	OSP foundation	Export cable
679	446	218	12	128	40

Table 4.16: Indicative number of days in which major vessels may be used during the construction period[8].

Activity	2015	2016 (Q2-Q4)	2017	2018	2019	2020 (Q1)
Piling	0	347	378	378	378	45
Substructures	0	116	126	126	126	15
Turbine installation	0	327	354	354	354	268
Inter-array cables		270	294	294	294	35
OSPs	15	8	15	15	8	0
Export cable	32	32				
Total	47	1098	1167	1167	1160	363

4.3.3 Assessment of significance

Assessment of collision risk

Injuries to marine mammals from ship strikes may not always result in immediate death, resulting in individuals becoming vulnerable to secondary infections or predation. Typically, injuries from ship strikes fall into two categories: blunt force trauma from impact and lacerations from propellers.

[7] Figures are indicative only and are dependent on vessel utilised and mobilisation strategy. "Movement" refers to the transit to and from the construction port and the centre of the site.

[8] Based on the maximum number of turbines to be installed built over the longest time period. Includes only the duration of the activity in question from arrival at the turbine until activity is completed. Does not include movements to and from port as duration is dependent on location which is yet to be confirmed.

The number and severity of strikes is thought to be influenced by vessel type, speed and underwater background noise. Vessels travelling at a speed of 14 knots or over appear to cause the most severe injuries, with sick or juvenile animals being the most vulnerable (Laist *et al.,* 2001). Some behaviour (i.e. social interaction or foraging) may further add to the risk of collision by reducing an animal's perception of risk (IWC, 2006).

A number of established shipping lanes pass close to (and through) the proposed development sites. These include transit to and from the Pentland Firth, in and out of Wick Harbour plus supply routes from Aberdeen to the Beatrice and Jacky oil fields.

As part of the impact assessment on local shipping and navigation (see ES Chapter 10.2: Shipping and Navigation), MORL carried out a series of AIS and radar surveys. As part of these surveys, vessel activity within 10 nm of the Moray Firth development zone, export cable route and proposed landfall site was monitored. The average number of vessels within this radius was 14 per day (see ES Chapter 5.2) with a large number of these associated with the Pentland Firth shipping route. The most common vessel types were cargo ships (28%) and fishing vessels (15%), with the majority of other vessel types recorded within the10 nm buffer zone were associated with the oil and gas industry.

Analysis of AIS tracks passing through the proposed sites over a 69 day period observed an average of two to three vessels per day, the majority of which were again fishing vessels and cargo ships (see ES Chapter 5.2).

The suggested level of transits between port and the development site suggests that, if averaged over a five year construction period, activity would result in an average of 0.8 transects per day above existing levels. It should be noted, however, that multiple activities may occur simultaneously, which would increase traffic on a daily level for certain periods but would shorten the overall duration of the impact.

If each construction activity is taken in isolation, the number of transits between the site and shore would result in no more than two additional vessel transects within the Moray Firth above the existing level of traffic (see Table 4.17 below) per day of activity. For the majority of activities, the increase is less than one (averaged over the proposed activity duration). These calculations are based on the assumption that each working day is associated with a vessel transect to and from the construction site where, in reality, this is unlikely to be the case for all activities as some vessels may remain at site for several days.

Table 4.17: Indication of average vessel movements per day for individual construction activities. Calculations based on the indicated number of days over a five year construction period.

	Foundation piling	Sub-structure installation	WTG installation	Array cable installation	OSP foundation	Export cable
Indicated vessel movement	679	446	218	12	128	40
Indicated no. days	1526	509	1657	1187	60	64
Average vessel movement per day	0.45	0.88	0.13	0.01	2.10	0.63

A recently released report by SNH attempts to predict the consequences of disturbances from increased vessel traffic in the Moray Firth on the resident bottlenose dolphin population (Lusseau *et al*., 2011). A number of scenarios were modelled including the development of renewable fabrication facilities at Nigg (Cromarty Firth) and/or Whiteness Point (Ardersier). The models assumed that each scenario would result in an additional 100, 200 or 400 extra vessel movements (per site) within the Firth and that vessels would comprise of barges and other large commercial vessels. They also assumed that vessel movements would occur at either a roughly even rate throughout the year, or predominantly in the summer.

No scenarios for a Nigg Bay facility resulted in a large change in vessel distribution within the Firth, with the time spent by vessels in the most heavily used areas of the Firth increasing by 20 minutes per day. The amount of time vessels would occur in the vicinity of bottlenose dolphins would increase no more than one hour per year.

An Ardersier facility could result in a change in vessel distribution, primarily due to the fact that vessels leaving this port would be travelling through areas of the Firth that are currently not heavily used. The average increase in vessel presence in heavily utilised areas was 28 minutes per day. The time vessels would spend in the vicinity of dolphins increased up to an additional two hours per year for the 400 movement scenario. For the other scenarios it was less than one hour per year.

If both sites were to be used simultaneously resulting in an extra 400 vessel movements from each site (800 total), the increase in the amount of time dolphins would spend in the vicinity of vessels would increase by around 2.5 hours per year. The authors concluded that the amount of time dolphins were likely to spend in the vicinity of boats as a result of these scenarios is unlikely to result in population level effects, based on the small increase in exposure predicted combined with the fact that commercial traffic is predictable and less likely to have an effect on bottlenose dolphins than unpredictable recreational vessels.

While this report only focuses on one species, the coastal nature of this bottlenose dolphin population suggests that they would have the greatest chance of coming into contact with vessels; especially if the vessels transit through areas known to be frequented by the dolphins (as would be the case if a facility were developed at Nigg). The general distribution across the Moray Firth of the other species under investigation in this assessment suggests they have less potential to come into contact with vessels associated with wind farm and OFTI construction. Predictability of vessel movement by marine mammals is a key aspect in minimising the potential risks imposed by vessel traffic (Nowacek et a., 2001; Lusseau, 2003; 2006). The wind farm and OFTI construction support vessels under consideration would be slow moving along a predictable path, making it easier for marine mammals to predict vessel behaviour and avoid the shipping lane.

Given the limited number of additional traffic movements per day relative to existing shipping levels (see discussion above) and that the additional vessels associated with construction will predominantly be slow moving and predictable (following a designated shipping channel), the impact of increased vessel traffic during the construction phase on grey seals, harbour seals, harbour porpoises and minke whales is considered to be **of low magnitude, medium duration** and thus of **minor significance**.

Based on the results presented in SNH model, impacts of increased vessel usage on bottlenose dolphins, the cumulative impact of increased vessel traffic on the resident population of bottlenose dolphins is also considered to be **of low magnitude, of medium duration** and thus of **minor significance**.

The use of ducted propellers

Since 2008 there has been increasing concern over the number of seal carcasses washed up at various locations on the UK coastline, all displaying the same fatal ‘corkscrew’ injury. At the time of publication of this report, the majority of seals identified with “corkscrew” injuries have been female harbour seals (Thompson *et al*., 2010). Although no empirical evidence exists, one suggested mechanism for a number of these deaths is that female harbour seals are attracted to the vessels by the noise ducted propellers produce. Although there is currently no evidence for this, a proposed hypothesis is that such vessels may be producing sounds that mimic breeding males, but further work is required to confirm this (Thompson *et al*., 2010). Another suggestion, again related to noise, is that juvenile grey seals are attracted by sounds with a pulsating rhythm (such as those produced by propellers), mimicking conspecific calls (Thompson *et al*., 2010).

Ducted propellers operate with non-rotating nozzles which are encircled by a duct or passageway. Their use is prevalent in the shipping industry and has been since 1931. A report by SMRU (Thompson *et al*., 2010) cited that Kort nozzle ducted propellers are frequently utilised in high load vessels such as tugboats and fishing trawlers, as the loads increase the propulsive efficiency. Ducted propellers can also be found in a number of other vessels including offshore supply vessels, submarines and survey vessels.

The SMRU report also refers to dynamic positioning when considering potential mechanisms for injury to seals. Dynamic positioning (DP) is a computer controlled system to automatically maintain a vessel's position and heading using its propellers and thrusters. Position reference sensors, combined with wind sensors, motion sensors and gyro compasses, provide information to the computer pertaining to the vessel's position and the magnitude and direction of environmental forces affecting its position. This information allows the computer to calculate the steering angle and thruster output required to maintain the vessels position.

Dynamic positioning therefore does not necessarily refer to a specific thruster type, but is more a method of automatically controlling position. Many vessels not equipped with dynamic positioning equipment will manually maintain station using operator control of the thrusters (ducted propellers) to enable station keeping.

Based on the reported stranding data (Thompson *et al*, 2010), seals are considered to be at the greatest risk from ducted propellers in combination with use of dynamic positioning (or the manual equivalent), with breeding females being at particular risk.

Subacoustech Environmental Ltd have recordings of the noise produced by a ducted propeller vessel undertaking a pipe-laying operation. Noise modelling on the propagation of noise from this vessel was carried out as part of the assessment of impacts from the cable corridor geophysical survey proposed by MORL[9]. This modelling suggested noise from such a vessel would be audible to seals between 1.9 and 12 km from the vessel (Figure 4.11)[10]. These figures are calculated in the absence of background noise levels and therefore represent highly precautionary values. The distance between haul-out sites within the harbour seal SAC and the proposed developments is greater than 60 km.

The baseline shipping and navigation assessment (ES Chapter 5.2) describes how a variety of offshore support vessels, fishing vessels, cargo vessels and tankers were tracked every day (see discussion above). It can be assumed that a significant proportion of these vessels were equipped with ducted propellers and utilising dynamic positioning capabilities. Despite this, there has only been one case of a suspected spiral cut seal has been found within the Moray Firth (A. Brownlow, SAC, pers.comm.), found at Bunchew, in the inner Moray Firth during July 2011. The carcass, a young harbour seal, was found in an advanced state of autolysis but exhibited a trauma pattern similar to other reported deaths. If proven to be a genuine case, this will be the first recorded within the Moray Firth and will represent a different age group from those already reported elsewhere.

[9] 20110506 Seal impact technical report: Note A. 2011.
[10] Figure provided by Subacoustech Environmental. Produced using modelled noise propagation from measured DP vessel noise undertaking pipe-laying activity.

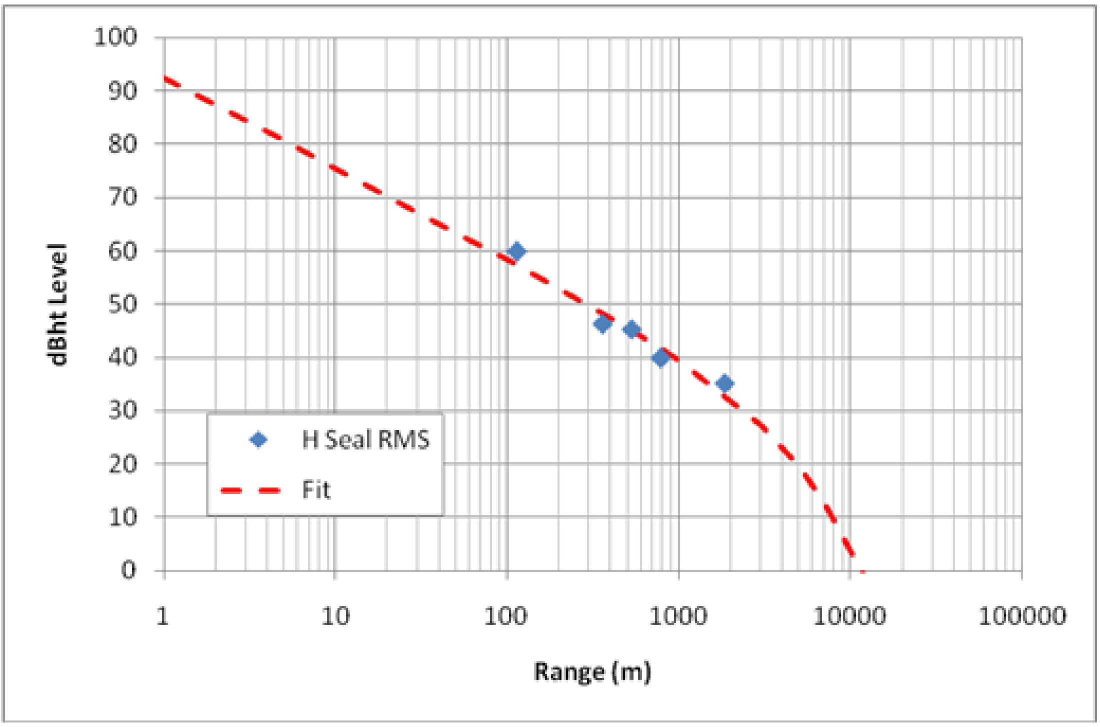


Figure 4.11: Predicted range that a vessel using ducted propellers would be audible to a harbour seal; the figure shows recorded levels (on a dB_{ht} scale) at a series of ranges from the vessel and the logarithmic fit to the data. It should be highlighted that this figure does not account for ambient noise levels and therefore is highly precautionary.

The Special Committee on Seals[11] (SCOS 2010) reports that the relatively small numbers of corkscrew seals found so far are unlikely to have a significant impact on large seal populations, although if the population in question were in significant decline (not the case within the Moray Firth), the current level of observed mortality may prove to be unsustainable.

Although the construction port has yet to be identified for the proposed MORL sites, much of the vessel movement associated with construction will be offshore. The greatest use of ducted propellers for dynamic positioning is likely to be within the construction area, over 55 km (30 nautical miles) away from haul-out sites within the inner Firth (including the harbour seal SAC), where construction activities are likely to act as self-mitigating deterrents, with the associated construction noise encouraging marine mammals to keep away from the area therefore reducing opportunities for harm.

Considering the uncertainty over the potential for injury, the knowledge that local seal populations are stable (increasing slightly in the case of harbour seals: refer to ES Chapter 4.4: Baseline Marine Mammals) and the small additional incremental risk when considered in the context of existing regional activities, the impact of ducted propellers is considered to be uncertain and of **low magnitude** and therefore **minor significance**.

[11] The National Environment Research Council (NERC) has a duty under the Conservation of Seals Act 1970 to provide scientific advice to the government on matters related to the management of seal populations. NERC appointed a Special Committee on Seals (SCOS) to formulate this advice.

OfTI landfall

A number of grey seal haul-out sites have been identified around the Fraserburgh area (and south towards Cruden Bay, approximately 23 nm south; SCOS, 2011; Duck, 2012). Taking into consideration the low number of individuals present at these sites, the uncertainty over the mechanisms behind corkscrew deaths and the fact that very few grey seal carcasses have been found exhibiting these wounds, the risk to grey seals from vessels equipped with ducted propellers associated with the installation of the offshore transmission cables is considered to be of **minor significance**.

4.4 Non-toxic contamination

4.4.1 Prediction of impact

Increases in turbidity as a result of construction activities could affect foraging, social interactions or predator/prey interactions of marine mammals. In addition, it may indirectly affect marine mammals by impacting potential availability of prey species.

4.4.2 Characterisation of potential impact

ES Chapter 6.2: Sedimentary and Coastal Processes discusses the impact that construction of the three proposed wind farms (Telford, MacColl and Stevenson) will have on local sedimentary processes, and ES Chapter 7.2: Fish and Shellfish Ecology discusses how these impacts will affect fish species. To summarise:

- The physical disturbance of the seabed associated with construction works will result in an increase in suspended sediment concentrations (SSCs) and subsequent sediment re-deposition;
- Primary sources of increased SSC would be from dredging associated with installation of gravity based foundations; drilling to install jacket pin piles; and cable trenching;
- Impacts of drilling and dredging on SSC are predicted to be within the natural range of variability for the area. Local effects around construction vessel may potentially be in excess of this but any increases would be localised and short-term;
- Increases in SSC during the installation inter-array cabling or of the offshore transmission cable would be relatively higher although again impacts would be short-term and largely localised to the installation vessel;
- The expected increases in SSC on fish species and associated sediment re-deposition were considered to be of small magnitude and minor significance.

This information is reviewed to assess direct and indirect impacts of increased SSC on marine mammals.

4.4.3 Assessment of significance

Around the UK, marine mammals are regularly recorded foraging in highly turbid environments such as estuaries and areas with strong tidal streams. Cetaceans, in particular, often appear to target such areas. Marine mammals are capable of foraging in very low light levels, having good hearing abilities and in the case of cetaceans, echolocation.

Cetaceans generally rely on hearing as opposed to vision to hunt, although dolphins can see well above and below water. It has been suggested pinnipeds rely on vision to hunt (Levenson & Schusterman, 1999) with reduced visual acuity in turbid waters (Weiffen *et al.*, 2006) although observations of healthy blind seals suggests otherwise (Newby *et al*., 1970). It has been suggested that under low visibility conditions, seals compensate using acoustic stimuli and their whiskers through sensitivity to hydrodynamic stimuli (Dehnhardt et al., 1998; 2001).

Generally, it is expected that marine mammals would be tolerant of any increases in suspended sediment, which is expected to be temporary and localised in effect. In reality, it is considered likely that marine mammals would avoid close contact with the activities likely to increase SSC and therefore unlikely to be directly impacted by any increases in SSC.

Therefore any direct impacts on marine mammals from increased SSC are considered to be **unlikely, of low magnitude** if they were to occur and **of negligible significance**.

Increases in SSC are predicted to be of minor significance to mobile fish species (Chapter 7.2: Fish and Shellfish Ecology) and therefore secondary impacts on marine mammals is also considered to be of **minor significance**.

5. Operational Phase Impact Assessment

5.1 Turbine operating noise

5.1.1 Prediction of impact

Offshore wind turbines, once operational, produce low frequency noise and vibrations that pass into the water column (Ingemansson Technology, 2003). While operational noise may be far lower than that produced during the construction and decommissioning phases of a wind farm, the duration is much longer and therefore has the potential to impact wildlife.

5.1.2 Characterisation of potential impact

The proposed sites (Telford, MacColl and Stevenson) will contain between 216 and 339 turbines of between 3.6 and 7/8 MW. Worst case scenario for the purpose of this assessment is 7 MW turbines.

Responses by marine mammals to turbines of similar size to these proposed turbines are not presently available, therefore a review of available information has been undertaken to help inform this assessment. In addition, Subacoustech Environmental Ltd has conducted SPEAR modelling predicting impact ranges for operational noise from 3 and 3.5 MW turbines based on recordings stored in their database. The results of this can be found in Table 5.1 below.

Table 5.1: Numerical output from SPEARS model predicting and comparing the impacts of different construction activities on marine mammals.

	90 dB_{ht} impact range (m)	90 dB_{ht} area of sea affected (km^2)	75 dB_{ht} impact range (m)	75 dB_{ht} area of sea affected (km^2)
Harbour seal	< 1	< 1	< 1	< 1
Harbour porpoise	< 1	< 1	< 1	< 1
Bottlenose dolphin	< 1	< 1	< 1	< 1
Minke whale	< 1	< 1	< 1	< 1

It has been concluded that noise from 1.5 MW turbines will not cause hearing damage in marine mammals but may affect behaviour (Betke *et al*., 2004). The zone of audibility for harbour porpoise from a 2 MW turbine has been estimated at between 8 - 63 m, but evidence suggests they may respond to operational noise up to 200 m from the turbine (Koschinski *et al*., 2003; Tougaard *et al*., 2009). Responses include avoidance and increased echolocation (Koschinski *et al*., 2003) although avoidance was less than that observed in pinger experiments (Culik *et al*., 2001). Harbour porpoise can appear cautious when confronted with a new stimulus (in this case, the noise vibrating from the turbine foundation) and explore the sound source with their sonar (Koschinski *et al*., 2003).

For harbour seals, the zone of audibility from a 2 MW turbine has been estimated at between 2.5 and 10 km (Tougaard *et al*., 2009). Masking of communication cues by turbine noise is thought to be insignificant for both harbour seals and harbour porpoise (Tougaard *et al*., 2009).

Work carried out at Barrow wind farm (eastern Irish Sea, Cumbria) indicated a marginal increase in low frequency noise compared to background from 3 MW turbines (Edwards *et al*., 2007). The increase was distinguishable from background noise up to a distance of 600 m from the turbines. Marine mammals observed in the area included harbour seal, harbour porpoise and bottlenose dolphin and from measurements taken at 5 m from the turbines, it was concluded that operational noise was unlikely to cause a behavioural response. Un-weighted noise measurements were of a sufficiently low level that direct physical injury (i.e. auditory damage, injury or death) was also considered unlikely.

Larger turbines than those discussed above may produce louder noise or peak energies at higher frequencies than those previously reported. Harbour porpoise have poor hearing capabilities within the noise frequency range produced by a 2 MW turbine, but a higher frequency noise may result in an increased response zone (Tougaard *et al*., 2009).

Furthermore, recent work on harbour and grey seal movements patterns around operational wind farms (Nysted and Rodsand II) in Denmark concluded that there was no significant effect of the wind farms on seal behaviour (McConnell et al, 2012). Monitoring studies around Egmond aan Zee have shown that porpoise activity increased once the wind farm was in operation. Whilst this is likely to be due to a reduction in fishing and other vessel traffic, this does highlight that operational noise has not deterred porpoises from using this area.

5.1.3 Assessment of significance

Evidence from existing wind farms suggest that physical injury or behavioural responses by marine mammals to turbine operating noise is unlikely, although it should be noted that existing data is from turbines of lower capacity than those proposed for these developments.

SPEAR modelling suggests that turbine operating noise will be less than that produced from a modern cargo ship and marine mammals have been shown to demonstrate a certain level of habituation to vessel traffic (see Section 4.1). Marine mammals have also been observed in close proximity to other fixed, noisy features such as drilling rigs and oil platforms.

It is not expected that marine mammals will suffer adversely from wind turbine operating noise. Any behavioural reactions that may occur will do so in the immediate vicinity of the foundations. Harbour porpoise have relatively poor hearing in the frequency ranges recorded to date from wind turbines (Tougaard *et al*., 2009) and, while seals have better hearing, they are more tolerant to underwater noise (Southall *et al*., 2007).

Although the impact of turbine operating noise is uncertain, it is predicted to be of **low magnitude**, only having the potential to affect marine mammals in very close proximity to the turbines. Therefore the impact of operational noise in marine mammals is considered to be of **negligible significant**.

5.2 Presence of turbines

5.2.1 Prediction of impact

A number of impacts may occur due to the physical presence of the turbines:

- Collision risk with turbine foundations;
- Barrier to movement resulting in restricted access to feeding or breeding grounds;
- Habitat loss for prey species.

5.2.2 Characterisation of potential impact

Based on information provided in the Rochdale Envelope, the minimum distance between turbines is predicted to be 840 x 600 m (see ES Chapter 2.2: Project description).

The footprint of the turbines (based on worst case scenario of 339 gravity-based foundations), scour and cable protection would result in loss of seabed area of 2.93 km^2, equating to 0.99% of total area of the three proposed wind farm sites combined (see ES Chapter 7.1: Benthic Ecology).

The footprint of the offshore substations, scour and offshore transmission cable protection will result in loss of seabed area of 0.29 km^2 (see ES Chapter 7.1: Benthic Ecology).

5.2.3 Assessment of significance

Wind turbine foundations are thought unlikely to represent a collision risk for marine mammals, being large and static (Inger *et al*., 2009). Wilson *et al*., (2007) proposed that fixed submerged structures are likely to pose little collision risk; while cables, chains, power lines and components freely moving on the surface or in the water column may pose a higher risk of collision for large species (e.g. baleen whales).

Offshore wind farms are generally considered unlikely to result in significant habitat loss, although inappropriate positioning of developments has the potential to cause deleterious effects for certain taxa (Inger *et al*., 2009), thus having the potential to indirectly impact marine mammals. Habitat loss will vary depending on the type and size of the installation, the location, whether it is situated in degraded or pristine habitat, and the stage of the life cycle of the installation (Inger *et al*., 2009). The greatest expected impacts would be during construction and decommissioning, resulting from direct habitat destruction, altered sedimentary process and noise (refer to ES Chapter 7.1: Benthic Ecology for more details).

Infrastructure associated with the seabed, particularly the turbine foundations, may act as artificial reefs (Linley *et al*. 2007), thus increasing the amount of available habitat for some taxa (i.e. prey species for marine mammals). Man-made structures positioned on the sea bed attract many marine organisms and are often used to enhance fisheries and rehabilitate local habitat (Clark & Edwards, 1999; Jensen, 2002). The presence of such structures have the potential to create new habitat capable of supporting epibiota and fish, and have been shown to increase density and biomass of fish compared to surrounding areas (Bohnsack *et al*., 1994; Wilhelmsson *et al*., 1998; Wilhelmsson & Malm, 2008).

Piers and oil platforms have been reported to attract marine organisms (Rilov & Benayahu, 1999; Love *et al*., 1999; Helvey, 2002). Greater abundances of fish have also been found in the vicinity of wind turbines compared to surrounding areas (Wilhelmsson *et al*., 2006), with little difference in species richness and diversity. A variety of marine organisms are also attracted to marine light sources (Marchesan *et al*. 2006; Harewood & Horrocks, 2008) which may be present on the structure.

No local effects from the presence of the Horns Rev I and Nysted wind farms have been reported for harbour or grey seals (Teilmann *et al*., 2006a; Tougaard et al., 2006b). In fact, the seal population at Rødsand (haul-out site near Nysted) increased during the operational years 2004 and 2005 (Teilmann *et al*., 2006b) although it is unclear at this stage whether this is related to the presence of the wind farm. Harbour seals have been observed within Horns Rev wind farm with no evidence of avoidance or changes in dive behaviour (Tougaard *et al*., 2006a). Similar observations were made within the Nysted and Rødsand II wind farms (McConnel *et al*., 2012), where both grey and harbour seals were tracked passing through the wind farm areas.

A decrease in harbour porpoise abundance at Nysted wind farm during the construction phase continued during the first two years of operation (Tougaard *et al*., 2006b). In contrast, no evidence for avoidance by harbour porpoise has been recorded at Horns Rev (Blew *et al*., 2006; Tougaard *et al*., 2006a). It has been suggested that this reduction in porpoise presence at Nysted could be due to the reduced competition for food in the Baltic Sea due to lower overall numbers of porpoise, in addition to the less favourable habitat at the site (Teilmann *et al*., 2006a).

Acoustic monitoring at the Egmond aan zee wind farm in the Dutch North Sea suggested an increase in harbour porpoise within and around the wind farm during the first two years of operation, in line with the general increase observed in Dutch waters during the last decade (Hammond *et al*., 2002; SCANS II 2008; Scheidat *et al*., 2011). The increase within the wind farm was more pronounced compared to reference areas, although the reasons for this are unclear (Scheidat *et al*., 2011) with increases in prey (reef effect) and shelter from disturbance (no fishing zones) being hypothesised.

Collision risk

Foundations are stationary and it is predicted that marine mammals would rapidly habituate to the presence of new structures in the area and therefore the risk of collision with turbine foundations is considered highly unlikely. Therefore, the risk of impact is predicted to be **low,** its **magnitude negligible** and its effects **not significant**.

Barrier to movement

Seals and harbour porpoise have been observed travelling freely between turbines in existing wind farms. In addition, the proposed development is not in the path of any known migratory routes (see ES Chapter 4.4: Baseline Marine Mammals). There will be sufficient distance between the proposed turbines to allow movement between them by marine mammals, therefore not creating a barrier to movement or restricting access to food sources. Therefore, the risk of impact is predicted to be **low,** its **magnitude low** and its effects **not significant**.

Habitat loss

The primary impact to marine mammals from loss of habitat would be through indirect impacts on potential prey species. The impacts of loss of habitat on fish species is discussed fully in ES Chapter 7.2: Fish and shellfish ecology. In general, the majority of impacts to fish species found in the Moray Firth were predicted to be minor and as a result, impacts to marine mammals though loss of habitat is predicted to minor, negligible and non-significant. In particular, impacts on sandeels, a common marine mammal prey species, are predicted to be low.

In conclusion, the risk of habitat loss from the physical presence of foundations within the proposed wind farms (Telford, Stevenson and MacColl) and the associated offshore transmission structure, leading to reduced prey availability for all marine mammal receptor species is predicted to be **low magnitude**, of long-term duration and therefore its effects **minor significance**.

5.3 Increased vessel use

5.3.1 Prediction of impact

Increases in local traffic associated with the operation and maintenance of an offshore wind farm and associated OfTI could increase the risk of collision for marine mammal species encountered within the Moray Firth.

5.3.2 Characterisation of potential impact

Section 4.3.2 above provides a detailed description of what is known about collision risk between marine mammals and vessel traffic. The precise details of vessel use during the operation phase are yet to be confirmed, although it is envisaged to be substantially less than the number of vessels operated during the construction phase. For example, it has been suggested that jack-up requirement during the operational phase could consist of five visits to each turbine over a 25 year period plus any reactive works required.

5.3.3 Assessment of significance

The basis for this assessment follows the same rational as described for collision risk during the construction phase, refer to Section 4.3.3 in this report for further details.

The types of vessel to be used during the operational phase of the wind farm and OfTI have not yet been decided, but it is suggested there would be significantly less transects than used during the construction phase and would therefore not represent a significant increase above the existing vessel activity within the Moray Firth.

The baseline site assessment studies found an average of between two and three vessels pass through the development area on a daily basis (see ES Chapter 8.2: Shipping and Navigation). If using the suggested jack-up scenario above as a guide, five visits to each turbine, totalling between 216 and 339 across the three sites depending on the turbines used, would result in between 1080 and 1695 visits over a 25 year period. This equates to a maximum 0.18 additional visits per day (above existing traffic) or one visit every five days. In practice, it is more likely that a jack up would go out and service several turbines at once rather than make isolated movements to site for each turbine. This pattern of servicing would produce concentrated periods of risk (although risk would still be minimal) and reduce the overall impact over the duration of the operation of the wind farm.

Given the predicted level of additional vessel traffic will be small compared to existing levels of traffic passing through the Moray Firth, the impact of increased vessel traffic during the operational phase on marine mammals is considered to be of **low magnitude and minor significance.**

The use of vessels with ducted propellers is likely but given the low number of vessels likely to be required and the distance between the proposed sites (Telford, Stevenson and MacColl), the potential effects of using vessels with ducted propellers is considered to be **low in magnitude** and **not significant**.

5.4 Electromagnetic fields

5.4.1 Prediction of impact

Transmission of electricity through cables, such as the frequently used high voltage direct current (HVDC) cables, will lead to the generation of electric and magnetic fields; both of which have been associated with the main feeder cables to shore from offshore wind farms (Gill *et al*., 2009).

It has been suggested that anthropogenic magnetic fields could affect animals such as bony fish (see ES Chapter 7.2: Fish and Shellfish Ecology), marine mammals and sea turtles that potentially use geomagnetic cues as an aid to navigation during migration, although the importance of these cues remains unclear (Wiltschko & Wiltschko, 2005; Luschi *et al*., 2007; Gould, 2008; Lohmann *et al*., 2008).

5.4.2 Characterisation of potential impact

Electromagnetic fields refer to two different types of field: electric fields (E-field) and magnetic fields (B-field). Power cables are capable of producing both due to the potential voltage differentials between the conductor and earth ground. Electric fields are expressed in units of kilovolts per meter (kV/m). A magnetic field produced by an electrical current can be expressed in Tesla (T).

The type of field produced and its strength will depend on the voltage and current (AC or DC) which passes along the cable. Electric fields are produced by voltage while magnetic fields are generated by the flow of current. Both increase in strength with increasing current or voltage (Portier & Wolfe, 1998). The effects of these fields on the surrounding environment will depend on the type of cable, its insulation, construction parameters, orientation and configuration.

An electric field will be largely kept within the cable but the magnetic field will not. The magnetic field can induce a secondary electric field (iE-field) in any nearby conductors. The strength of this induced electric field will be dependent on the distance from the cable, the strength of the magnetic field, and the speed, direction of flow and chemical composition of the surrounding water.

The types of cables intended to be used within the proposed development can be found in Table 5.2 below.

The length if inter-array cabling is estimated to be between 232 and 572 km and inter-OSP cabling will total between 38 and 90 km in length. Cables will be buried to a target depth of 1 m with a single cable in each trench. Should burial not be possible, cables will be protected by other methods such as rock placement, concrete mattresses or grout bags (see Chapter 2.2: Project Description for further details).

Table 5.2: Details of cables proposed for the developments.

	Voltage	Insulation	Cable type	Trench depth
Inter-array cable	33-66 kV AC	Solid polymeric or rubber	Three core, offshore grade. Copper or aluminium cores.	1 m (0-3 m)
Inter-OSP cable	220 kV AC	Solid polymeric	Three core, offshore grade. Aluminium copper cores.	1 m (0-3 m)
Export transmission cable	320 kV DC	Solid polymeric	Single core of either copper or aluminium.	1 m (0-3 m)

The offshore transmission cables will be approximately 105 km in length (wind farm to Fraserburgh landfall) with the final length determined by the final project design. Cable burial will be as for the inter-array cables apart from their being two cables within a single trench with two parallel trenches running between the wind farm sites and the shore.

5.4.3 Assessment of significance

As previously stated, an electric field will be largely kept within the cable but a magnetic field will not. Two categories of organisms exist that can detect magnetic fields, those which can detect the electric fields induced by magnetic fields (iE-fields), and those that detect magnetic fields based on a mechanism related to magnetite deposits.

The majority of species which can detect iE-fields are elasmobranchs, and it is thought that this ability is used mainly for navigation (see ES Chapters 7.2 and 10.2: Fish and Shellfish for further details). A large number of organisms are thought to use geomagnetic fields associated with the earth's magnetite deposits to navigate. Evidence suggests this includes cetaceans, with a number of species thought to respond to magnetic fields including harbour porpoise, bottlenose dolphins, humpback whales and fin whales (CMACS, 2005). A number of live cetacean strandings have been linked with local geomagnetic anomalies (Kirschvink *et al.,* 1986) or with disruptions in the normal patterns of daily geomagnetic fluctuations (Klinowska, 1990), suggesting that cetaceans are capable of sensing geomagnetism and of using geomagnetic cues for navigation, although no system of reception has been identified (Zoeger *et al*., 1981). There are no indications in the literature that seals are sensitive to magnetic fields (Fauber Maunsell & Metoc, 2007).

Geomagnetic fields of less than 50 nT are thought to be enough to influence the stranding of some cetacean species (Kirschvink *et al*., 1986). Magnetic fields created by transmission cables in offshore wind farms can be between 30-50 μT (Eltra, 2000) and so has been suggested may be able to influence the navigation of marine mammal (Hoffman *et al*., 2000).

Modelling undertaken by COWRIE (CMACS, 2003) for a standard offshore wind farm 3 core 132 kV AC cable found that the sheath provided effective insulation from the E-fields but not the B-fields. A strong magnetic field of 1.6 µT was predicted within millimetres of the cable, adding to the natural background level of approximately 50 µT. It was predicted this field would be non-distinguishable from background within 20 m of the cable (CMACS, 2003). Field measurements of B-fields made at the River Clwyd Estuary from 33 kV cables were 50 μT_{RMS}[12] and fell rapidly to 10 μT_{RMS} at 5 m from the cable.

Normandeau *et al*., (2011) modelled expected magnetic fields using design characteristics of 24 undersea cable projects, and found for eight out of the ten AC cables modelled, intensity of the field was roughly a direct function of voltage (ranging from 33kV to 345kV). Average magnetic field strengths from AC cables buried at 1 m were predicted to be less than 10 µT at the cable with strength dissipating rapidly with distance (Normadeau *et al*., 2011).

As with AC cables, magnetic fields from DC currents (i.e. the offshore transmission cables) also decrease with distance from the cable. Normadeau et al., (2011) predicted the field strength from DC cables would be 78 µT at the cable, dropping to less than 10 µT within 5 m of the cable.

Behavioural responses to magnetic fields generated by AC and DC currents from cables used in offshore wind farms are unclear. Information on the influence of such fields on marine mammals is very limited, with much of the available evidence concentrating on fish. For example, a study at Viedeby Offshore Wind Farm concluded that B-fields may be strong enough to affect magneto-sensitive fish but only to a distance of 1 m from the cable when the field was 33.1 µT (3 phase 10 kV 50 Hz cable carrying 260 A: Bioconsult, 2002).

There is no evidence to date suggesting a change (positive or negative) in marine mammal activity related to magnetic fields from cables used for generating power from offshore wind farms. Harbour porpoises continue to migrate in and out of the Baltic Sea over sub-sea HVDC cables, although this is a different type of cable than would be present at the proposed developments (Basslink, 2001). It is thought magnetic fields from cables could potentially to be detected by cetaceans as a new localised addition to heterogeneous pattern of geomagnetic anomalies in the surrounding area (Basslink, 2001).

Where possible, cables associated with the proposed wind farm sites (MacColl, Telford and Stevenson) and the associated offshore transmission will be buried underground to a target depth of 1 m. In areas where this is not possible, cables will be protected by a layer of rock or concrete. Evidence suggests that magnetic fields may only be detectable above background in the immediate vicinity of the cable, and will dissipate rapidly with distance.

Therefore, although unproven, it is considered that potential impacts of magnetic fields produced by transmission cables on marine mammals will be **negligible** if at all, and therefore **not significant**.

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[12] RMS = the 'square root of the mean squared' used by engineers to describe levels of alternating signals. i.e. current flow in power cables goes first in one direction then reverses. RMS is the equivalent current flowing in one direction continuously that would supply the same amount of electrical power.

5.5 Toxic contamination

5.5.1 Prediction of impact

Once a wind farm is operational, leaching of toxic compounds from sacrificial anodes or antifouling paints, if present, into the water column have the potential to contaminate marine mammals and their food supply.

5.5.2 Characterisation of potential impact

The Rochdale Envelope discusses the potential for cathodic protection, anti-fouling coatings and mechanical removal of deposits. A full assessment of requirements for corrosion protection and management of deposits on substructures will be made at a later date so for the purpose of this assessment a general review of potential impacts is presented.

One method of preventing the corrosion of metallic structures in seawater is to apply cathodic protection. This process involves making an electrical connection between the ferrous metal and a block of another metal also immersed in the water, establishing an electrochemical cell. The flow of electrical current within this cell results in accelerated corrosion at the anode and a reduction in corrosion at the ferrous cathode. In order to maintain protection, it is necessary to replace corroded anodes at regular intervals. The dissolution of anodes, often zinc or aluminium, can be a contributory factor to metal contamination in the marine environment.

Antifouling paints are applied to the hulls of boats and submerged static structures such as piers, pipelines and drilling platforms to prevent the growth of fouling organisms (Voulvoulis *et al*., 2002; Konstantinou & Albanis, 2004; Chambers *et al*., 2006; Ameida *et al*., 2007). On moving vessels, accumulation of algae and invertebrates increase friction and resistance of the vessel moving though the water resulting in greater fuel consumption and poorer manoeuvrability. Fouling on static structures may compromise safety by reducing stability and concealing structural defects.

The use of tri-butyl-tin (TBT) was banned in 2008; modern antifouling coatings contain CU(I)-based biocidal pigments (e.g. cuprous oxide) and sometimes zinc oxide, although zinc is more generally used as a booster (Watermann *et al*., 2005). The paint may be further enhanced by the inclusion of secondary boosters such as zinc and copper pyrithione, Irgarol 1051, ziram or diuron (Turner, 2010). Antifouling occurs through the slow controlled leaching of biocides from the painted surface. The dissolution of copper is sensitive to temperature, pH and salinity (Turner, 2010). Biocidal concentrations develop in the leach layer in the immediate vicinity of the surface and have the potential to accumulate in the water column (Tolhurst *et al*., 2007), particularly in poorly flushed environments.

Accumulation of metals in the marine environment from either source can result in increased levels of contaminants in benthic communities, thus entering the food chain and causing a potential hazard to many animals including marine mammals (Schratzberger *et al*., 2002; Gammon *et al*., 2009).

5.5.3 Assessment of significance

Marine mammals are exposed to heavy metal contaminants present in the water. The primary route for contamination is through contaminated prey items although absorption through the skin and across the placenta can also occur (Das *et al*., 2000). As top predators, they are particularly at risk from the bio-accumulation of contaminants in the food chain (Bouquegneau & Joiris, 1998; Svensson *et al*., 1992; Nakagawa *et al*., 1997).

The heavy metals of greatest concern are cadmium, lead, zinc and mercury, all of which are frequently found in high concentrations in the liver, kidney and bone of mammals. Marine mammals have a number of mechanisms to aid detoxification of metals including the production of metallothioneins (proteins) which are involved in the homeostasis of essential metals (i.e. zinc and copper). These proteins are also involved with the detoxification of non-essential metals like cadmium and mercury, resulting in marine mammals being able to tolerate relatively high levels of some metals in their diet (Das *et al*., 2000; Ikemoto *et al*., 2004). Heavy metal contamination has been associated with reduced resistance to infections including parasitic infections (immunosuppresion: Bennett *et al*., 2001; Siebert *et al*., 1999) and central nervous system damage (Wagemann *et al*., 1988).

Which systems will be utilised to protect the turbine foundations from the environment will be decided once the foundation types have been finalised. Much of the research into contamination from antifouling paints and sacrificial anodes has taken place either in the laboratory or concentrated on estuaries and harbours (i.e. Bird *et al*., 1996; Matthiessen *et al*., 1999; Comber *et al*., 2002; Warnken *et al*., 2004; Zamora-Ley *et al*., 2006; Di Landa *et al*., 2009; Lam *et al*., 2009). Generally, higher levels of contamination have been associated with areas of high vessel capacity (i.e. harbours) and or with little water flow, thus allowing concentration to build.

Should such systems be used on the turbine foundations within the proposed development, being located in the centre of the Moray Firth they will be subjected to regular tidal movements with peak spring current speeds of 0.45-0.5 m/s having been recorded (see ES Chapter 3.4: Hydrodynamics), thus aiding the dissipation of leached metals. Added to which, inherent to the design of both systems is that metals (or biocides in the case of antifouling) are leached at a very low, slow rate.

Given that such systems are likely to be present in some form or another on every shipping vessel within the Moray Firth, it is not felt that any additional load to metal concentrations within the Moray Firth will occur as a result of such systems being used to protect turbine foundations. As a result, impacts to marine mammals are considered **unlikely** and **not significant**.

6. Decommissioning Impact Assessment

The decommissioning of an offshore wind farm may involve the use of cutting tools or occasionally open water explosives.

Current cutting techniques include mechanical and abrasive cutting. Both would generate noise near the turbine foundation. No data are available at this time on noise levels produced by cutting mechanisms underwater but it would be expected to be substantially lower than noise levels created during the construction phase, in particular from piling.

Underwater explosions are the strongest point source of anthropogenic noise in the marine environment (Richardson *et al*., 1995) and can potentially cause disturbance, injury and death of marine mammals (Fitch & Young, 1948; Trasky, 1976; Kilma *et al*., 1988; Zhou Kaiya & Zhang Xingduan, 1991; Baird *et al*., 1994; Ketten, 1995; Ketten *et al*., 1993). However, their use is not expected at this stage during decommissioning.

The MORL decommissioning programme has not yet been finalised and will be dependent on the choice of turbine structure, therefore a detailed assessment is not possible at this stage. Based on existing cutting techniques, is suggested that potential impacts would be of **low magnitude, of medium duration** and of **minor significance**.

7. Cumulative Impact Assessment

This section presents the results of assessment of the potential cumulative impacts upon marine mammals arising from the proposed Telford, Stevenson and MacColl offshore wind farms and offshore transmission infrastructure in conjunction with other existing or reasonably foreseeable marine and coastal developments and activities. MORL's approach to the assessment of cumulative impacts is described in ES Chapter 1.3: Environmental Impact Assessment.

The projects that are considered within this assessment are listed in Table 7.1 below.

Table 7.1: Cumulative developments considered within the assessment.

Within Moray Firth	• Proposed MORL Eastern Development Area (EDA); • Potential MORL Western Development Area (WDA); • Proposed MORL Offshore Transmission Infrastructure (OFTI); • Proposed MORL Meteorological Mast; • Proposed Beatrice Offshore Wind Farm Ltd (BOWL) wind farm; • Proposed BOWL Offshore Transmission Infrastructure; • Oil and Gas activities; • Proposed SHETL offshore hub and cable; • Potential port and harbour developments within Moray Firth; • Ministry of Defence (MoD) activities;
Outwith Moray Firth	• European Offshore Wind Deployment Centre (EOWDC) in Aberdeen Bay; • All proposed Forth and Tay offshore wind projects; and • Proposed Pentland Firth and Orkney wave and tidal developments.

The key receptor species to be assessed are grey seal; harbour seal; harbour porpoise; bottlenose dolphin and minke whale. The potential cumulative impacts under consideration are:

- Permanent hearing damage resulting from increased noise from piling within the proposed MORL and BOWL developments;
- Temporary displacement resulting from increased noise from piling within the proposed MORL and BOWL developments;
- Increased collision risk from vessels associated with the proposed MORL, BOWL and the SHETL cable route developments;

- Reduction in prey due to construction activities associated with the proposed MORL, BOWL and the SHETL cable route developments;
- Changes in prey availability due to infrastructure associated with the proposed MORL, BOWL and the SHETL cable route developments;
- Potential cumulative impacts between the proposed MORL developments and oil and gas developments within the Moray Firth;
- Potential cumulative impacts between the proposed MORL developments and MOD activities (i.e. low flying aircraft) within the Moray Firth; and
- Cumulative impacts between activities within the Moray Firth and proposed developments outside of the Moray Firth (i.e. proposed Forth and Tay developments).

The following activities/impacts have not been considered within this cumulative assessment as their potential effects were considered not significant in the primary assessment:

- Risk of stranding from electromagnetic fields generated by transmission cables;
- Long-term avoidance resulting from the presence of offshore structures including generating station operating noise;
- Prey contamination due to toxic (heavy metal) contamination from use of sacrificial anodes and antifouling paints.

This assessment is broken down into two sections:

7.1: Cumulative impacts within the Moray Firth; and

7.2: Cumulative impacts out with the Moray Firth.

7.1 Cumulative impacts within the Moray Firth

The projects under consideration in this part of the assessment are the BOWL offshore wind farm and transmission infrastructure, and the SHETL hub and cable.

It is proposed that the Western Development Area will contain between 88 and 140 generating stations depending on the capacity of the turbines (5 or 7 MW), with the decision being dependant on the final capacity of the EDA. As a result, a detailed discussion regarding the cumulative impacts of the WDA has not possible within this assessment.

A summary of proposed construction timetables based on information available at the time of publishing can be found in Table 7.4 below.

Table 7.4: Representation of possible the construction programmes for developments within the Moray Firth under consideration in the cumulative impact assessment (CIA). The dark grey squares illustrate the minimum possible construction period with the blue squares the maximum depending on construction timetables.

	2012	2013	2014	2015	2016	2017	2018	2019	2020
MORL (EDA & WDA)									
BOWL									
SHETL[13]									

The proposed BOWL development will involve the installation of between 142 and 277 turbines, depending of the final choice of turbine and three OSPs. A number of foundation types are being investigated including:

- Mono-towers and gravity base;
- Jacket and pin piles;
- Jacket and suction piles; and
- Jacket and gravity base.

Construction is planned to begin in 2014 and will last either two or three years depending on the final construction timetable.

SHETL are proposing to install subsea cable between Shetland and Portgordon on the southern Moray coast. Cable burial along the 320 km route will be achieved through jetting or ploughing techniques to a target depth of 1 m. Subsea cable installation is timetabled for 2013, prior to construction beginning of the proposed offshore wind farm developments (MORL and BOWL).

[13] Predicted timetable for installation of subsea cables.

7.1.1 Elevated anthropogenic noise

The noise propagation and impact modelling described in Section 4.2.2 of this report was extended to include the cumulative impacts of piling between the three proposed sites (MacColl, Telford and Stevenson) and the neighbouring BOWL site. The degree of conservatism built into the modelling process can be found in Section 4.2.2.1, Table 4.7.

Three scenarios were modelled, see Table 7.5 below for details (and see Appendix 7.3 F for model outputs).

Table 7.5: Piling locations used for CIA modelling scenarios. Please refer to Figure 01 in Appendix 7.3 F for visual representation.

D)	**Two vessels piling within the BOWL site for two years (2014-2015) immediately followed by two vessels piling within the MORL site for three years (2016-2018).**
The locations A & B where chosen as representative of worst case spatially as they are closest to the sensitive receptors. Construction is modelled to start in 2014, followed by 3 years across Telford, Stevenson & MacColl (again utilising two vessels during this construction phase, modelled as locations 1 & 5, representative of worst case spatially due to the noise impact from these two locations covering the largest area of sea). This model therefore represents a 5 year build out programme ending in 2018.	
E)	**One vessel piling within the BOWL site for three years (2014-2016), overlapping with a single vessel piling within the MORL site during 2016 followed by four years of a single vessel on MORL only.**
Three years construction at BOWL utilising one vessel. Modelled based on piling occurring at location A, being indicative of the worst case scenario spatially as this location is nearest to the receptors. Construction is modelled to start on BOWL in 2014 for three years, and MORL in 2016 for five years. MORL modelled to utilise a single vessel, modelled piling at location 1 as the worst case scenario as is closest to the receptors. This model therefore represents a seven year build out with construction on both sites overlapping for one year (2016) and the complete program ending in 2020.	
F)	**Two piling vessels working within each site simultaneously (total of eight vessels) resulting in a two year construction period.**
A two year program in which all four wind farms are built out together. This scenario would start in 2016, with the model scenarios based on there being piling at locations A & B on the BOWL site and 1-6 locations on the 3 MORL sites.	

In order to obtain the required construction combinations for this assessment, the modelling of perceived noise propagations and associated behavioural displacement, along with SAFESIMM modelling to predict potential PTS exposure, were undertaken in annual stages. This presents a difference from the modelling undertaken for the Generating Station and the OfTI works, in which disturbance and potential for PTS onset were modelled for the first year of construction, and then equal levels of disturbance and PTS onset assumed for all subsequent years of the construction phase. The annual noise modelling outputs presented in Technical Appendix 7.3 F for the cumulative assessment were then used to calculate the maximum number of animals potentially displaced and to suffer PTS onset (through SAFESIMM) over the course of the full construction phases of both projects.

Figure 01 in Technical Appendix 7.3 F shows the location of piling installations modelled for each Scenario.

Details of the inherent conservatism that is purposefully adopted in the assessment methodology can be found in Section 4.2.2.1, Table 4.7. These assumptions include that a) displacement will lead to reduced fitness and a failure to breed in the affected year and b) that individuals experiencing PTS are subjected to an additional 25% mortality risk. The modelling was undertaken as described in Section 4.2 above, and Table 7.6 below provides the numerical outputs from this modelling process for the Scenarios assessed. Separate values are presented for the different phases within each scenario. The figures in brackets within the table represent the number of individuals expressed as a percentage of the Moray Firth populations or SCANS II Block J for minke whales[14]. The seal PTS onset were modelled using 186 dB SELs and cetaceans using 198 dB SELs. The number of individual harbour seals and bottlenose dolphins modelled to experience potential displacement and PTS onset were then used in population modelling for both species, the results of which are presented as Figures 7.3 and 7.4 below.

[14] The details of these population estimates for each species can be found in Chapter 4.4: Baseline Marine Mammals. The population of minke whales potentially subject to the impacts of the MORL construction phase was taken to be 1,462, based upon SCANS II model estimates for block J (which includes the Moray Firth).

Table 7.6: Predicted number of individuals affected by piling noise each year of construction for each project. Figures in brackets represent the number of individuals expressed as a percentage of the Moray Firth populations. Seal values modelled using 186 dB and cetaceans using 198 dB.

Scenario D					
	Harbour seal	Grey seal	Harbour porpoise	Bottlenose dolphin	Minke whale
PTS					
2014-2015 (BOWL)	237.2 (20.5%)	347.5 (10.9%)	12.9 (0.2%)	0.11(0.1%)	24.7 (1.7%)
2016-2018 (MORL)	197.5 (17.1%)	301.3 (9.5%)	10.2 (0.2%)	0.07 (<0.01%)	10.7 (0.7%)
Behavioural displacement each year for the total spread of the construction vessels					
2014 – 2015 (BOWL)					
High	813 (68.8%)	1604 (44.6%)	4343 (71.0%)	33 (17.0%)	214 (14.6%)
Best fit	613 (51.8%)	1101 (30.6%)	3263 (53.3%)	20 (10.3%)	179 (12.2%)
Low	66 (5.6%)	80 (2.2%)	383 (6.3%)	1 (0.5%)	25 (1.7%)
2016 – 2018 (MORL)					
High	823 (69.6%)	1656 (46%)	4056 (73.7%)	33 (16.8%)	218 (14.9%)
Best fit	629 (53.2%)	1184 (32.9%)	3442 (56.3%)	19 (9.7%)	185 (12.7%)
Low	66 (5.6%)	94 (2.6%)	367 (6.0%)	1 (0.3%)	27 (1.8%)
Scenario E					
	Harbour seal	Grey seal	Harbour porpoise	Bottlenose dolphin	Minke whale
PTS					
2014 – 2015 (BOWL)	168.6 (14.6%)	236.5 (7.5%)	8.2 (0.1%)	0.07 (<0.1%)	35.4 (2.4%)
2016 – 2016 (BOWL + MORL)	210.1 (18.1%)	300 (9.5%)	11.5 (0.2%)	0.1 (0.1%)	24.2 (1.7%)
2017 – 2020 (MORL)	120.9 (10.4%)	170 (5.4%)	6.4 (0.1%)	0.06 (<0.1%)	12.3 (0.8%)
Behavioural displacement each year for the total spread of the construction vessels					
2014 – 2015 (BOWL)					
High	785 (66.4%)	1457 (40.5%)	4283 (70.0%)	32 (16.3%)	213 (14.6%)

Best fit	582 (49.2%)	966 (26.9%)	3191 (52.2%)	19 (9.6%)	177 (12.1%)
Lower	57 (4.8%)	63 (1.7%)	347 (5.7%)	1 (0.4%)	23 (15.7%)
2016 – 2016 (BOWL + MORL)					
High	810 (68.5%)	1484 (41.3%)	4376 (71.5%)	35 (17.8%)	214 (14.6%)
Best fit	609 (51.4%)	995 (27.7%)	3312 (54.1%)	21 (10.7%)	179 (12.2%)
Lower	64 (5.4%)	72 (2.0%)	392 (6.4%)	1 (0.4%)	25 (1.7%)
2017 – 2018 (MORL)					
High	731 (61.8%)	1159 (32.2%)	4015 (65.6%)	31 (15.7%)	206 (14.1%)
Best Fit	522 (44.1%)	739 (20.5%)	2933 (47.9%)	17 (8.9%)	168 (11.5%)
Lower	42 (3.5%)	45 (1.3%)	263 (4.3%)	0 (0.2%)	20 (1.4%)
Scenario F					
	Harbour seal	**Grey seal**	**Harbour porpoise**	**Bottlenose dolphin**	**Minke whale**
PTS – Values provided here are for six vessels in MORL plus those numbers for two vessels in BOWL. MORL appreciate that this represents a series of double counting and thus over-representation of effects					
2016 - 2017	542 (46.3%)	826 (18.4%)	35 (0.6%)	0.23 (0.2%)	34.6 (2.4%)
Behavioural displacement each year for the total spread of the construction vessels					
High	888 (75.1%)	1850 (51.4%)	5151 (84.2%)	82 (41.8%)	223 (15.2%)
Best Fit	705 (59.6%)	1358 (37.7%)	4219 (69.0%)	67 (34.2%)	194(13.3%)
Lower	226 (19.1%)	138 (3.8%)	681 (11.1%)	7 (3.6%)	37 (2.5%)

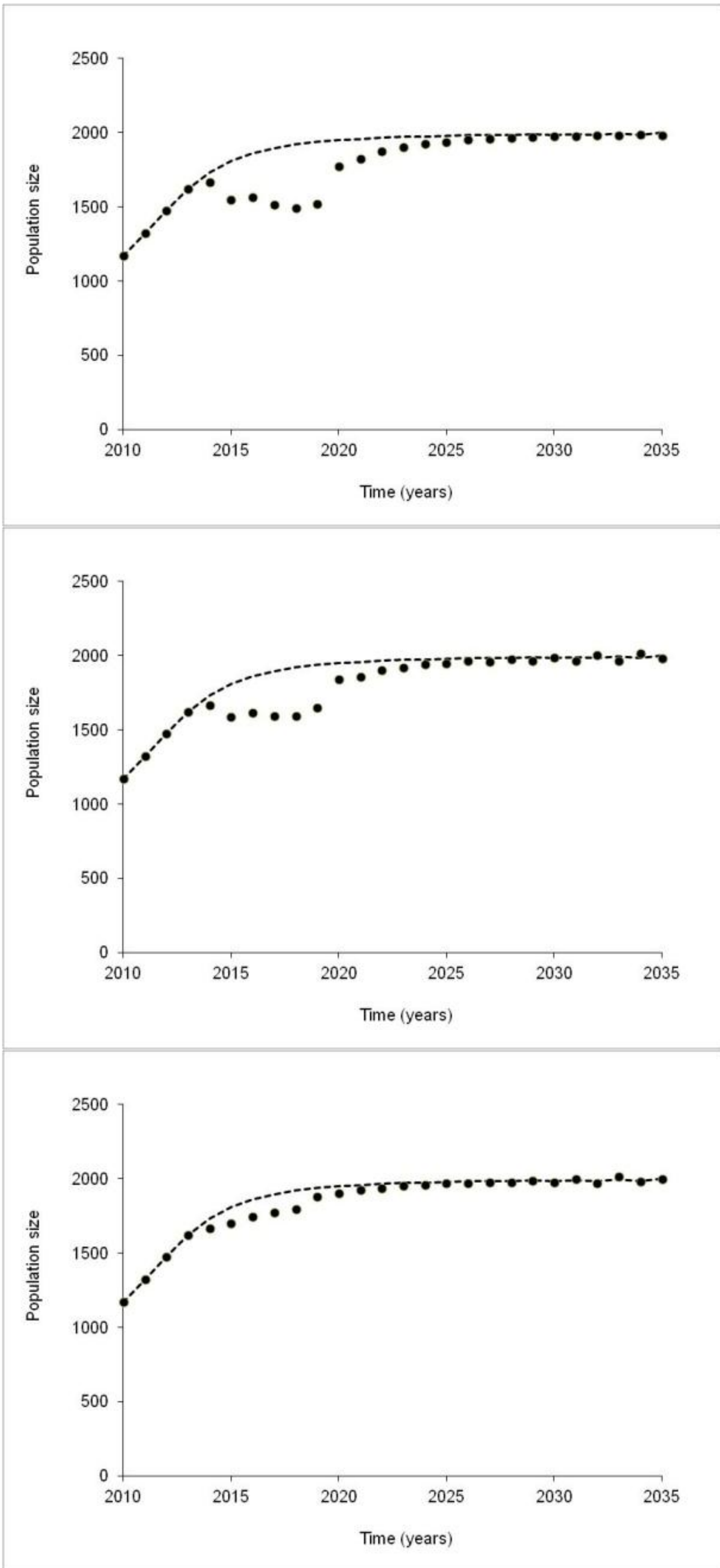


Figure 7.3a: Scenario D (BOWL followed by MORL) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.

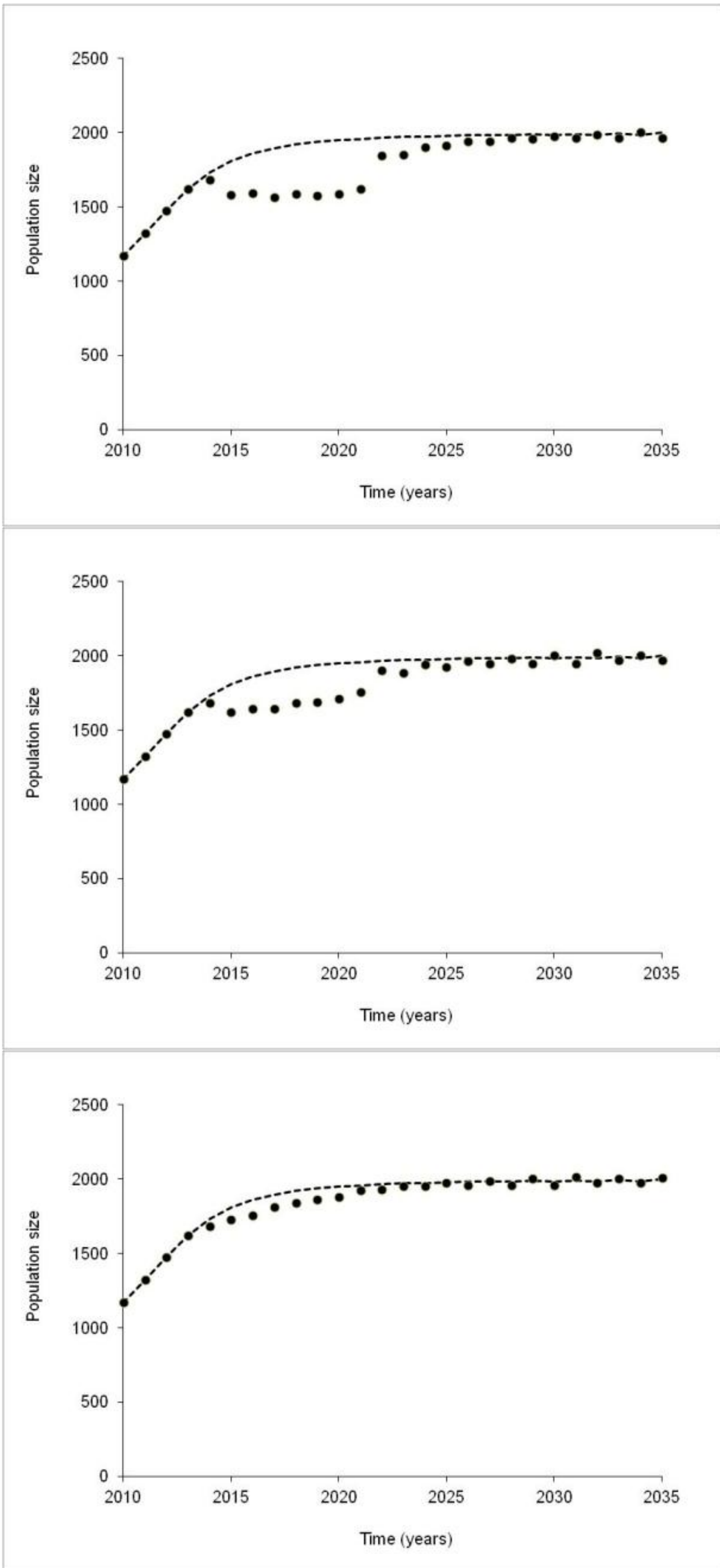


Figure 7.3b: Scenario E (BOWL overlapping for one year with MORL) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.

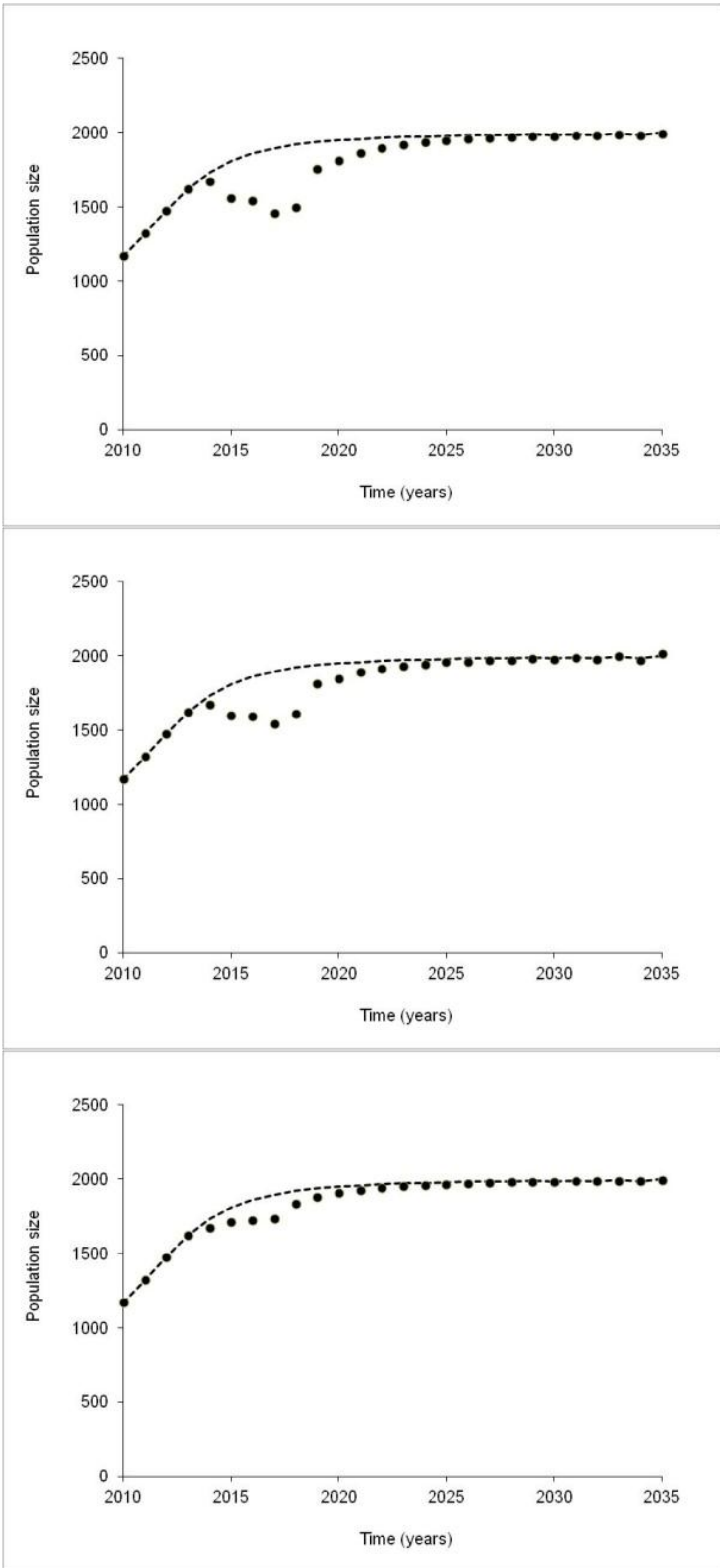
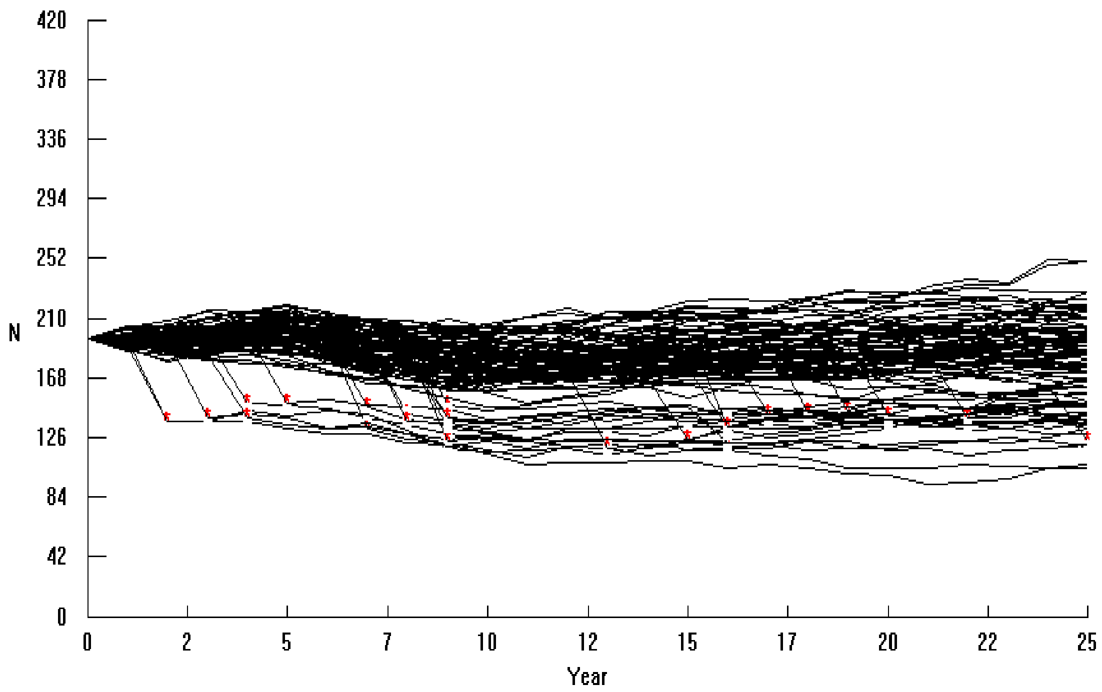


Figure 7.3c: Scenario F (BOWL coinciding with MORL) - population modelling for the harbour seal population in the Moray Firth. Data based on 186 dB SAFESIMM model outputs. From top to bottom: upper, best fit and lower prediction.



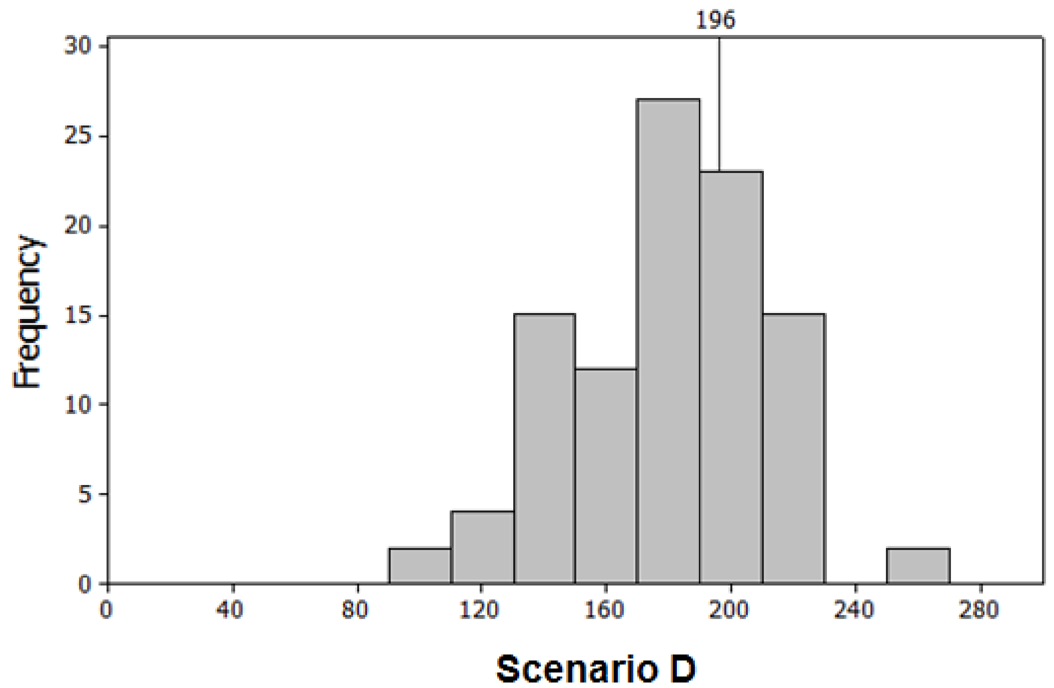
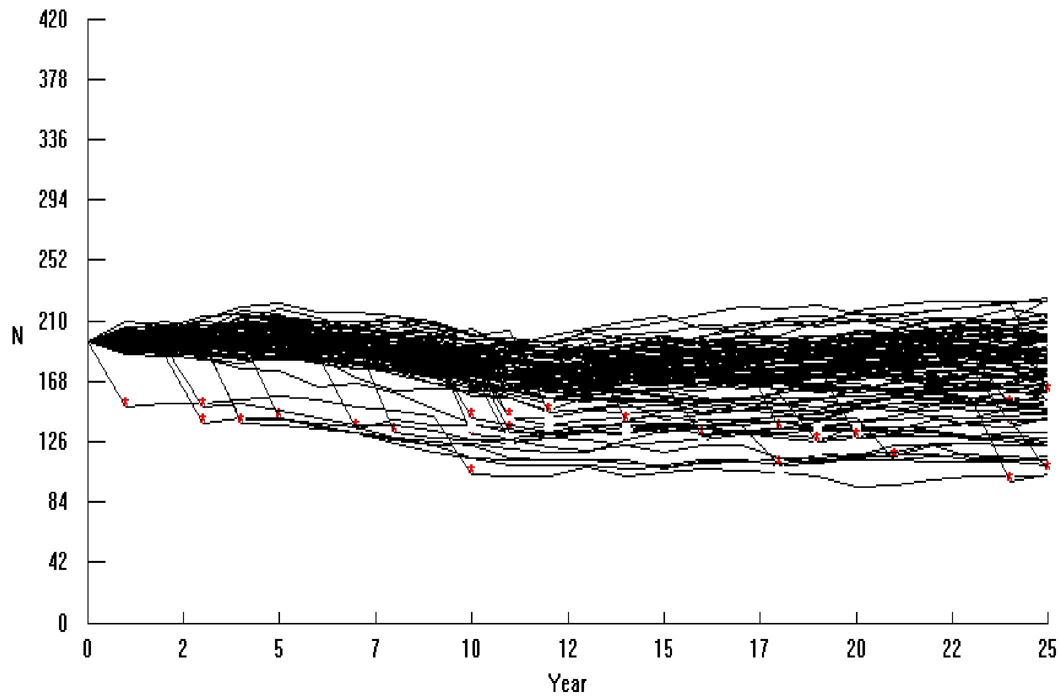


Figure 7.4a: Scenario D (BOWL followed by MORL) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.



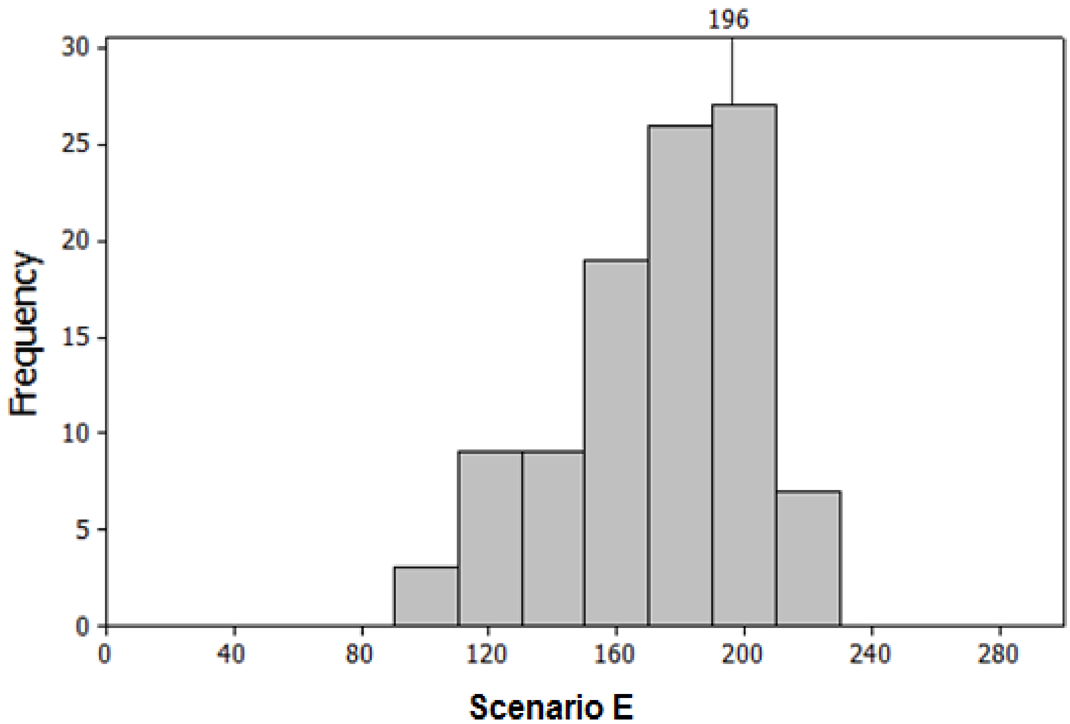
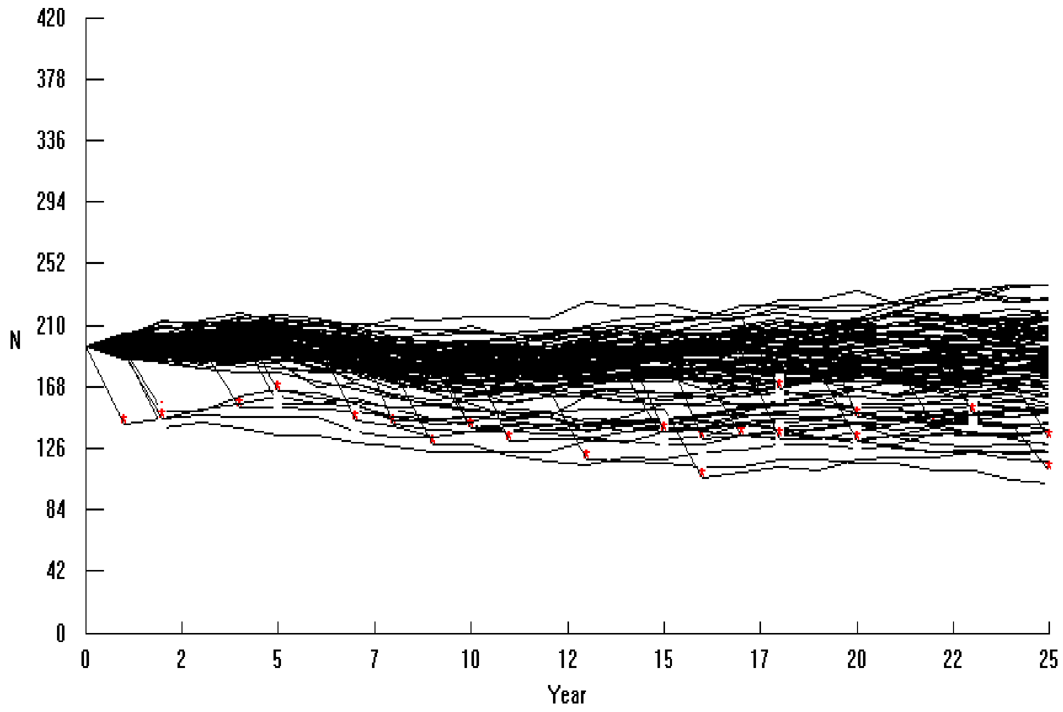


Figure 7.4b: Scenario E (BOWL overlapping with MORL for one year) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.



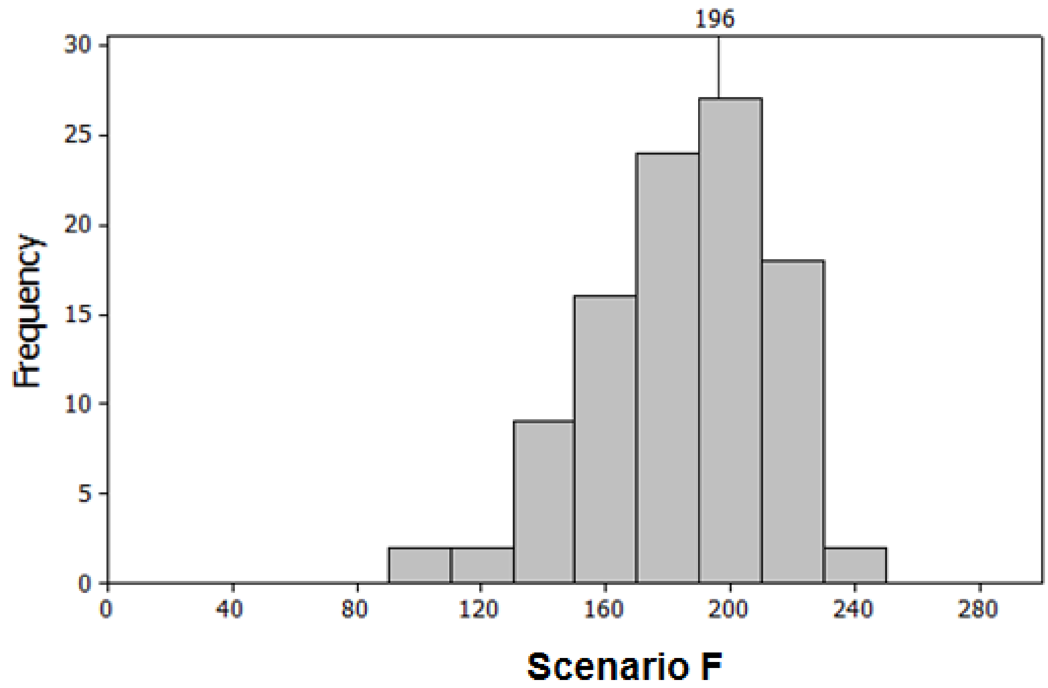


Figure 7.4c: Scenario F (BOWL coinciding with MORL) - population modelling for the bottlenose dolphin population in the Moray Firth. Data based on 198 dB SAFESIMM model outputs. Upper = population size graph; lower = frequency distribution of population size.

It can be seen from Table 7.6 that the increase in simultaneous piling activity between the BOWL and MORL sites leads to an increase in modelled noise related displacement and the potential for individual animals to experience PTS. Alternatively, decreasing the number of simultaneous piling events reduces the number of modelled displaced individuals and those with the potential to experience PTS, while extending the duration of both effects. Comparison of the effects modelled to occur from the two proposals (BOWL and MORL) show similar predicted effects for both projects, although the effects from piling within the BOWL site are predicted to be slightly higher than those from the MORL sites due to the BOWL development being closer to the inner Firth and preferred foraging grounds (see seal tagging studies in Technical Appendix 4.4 A: Baseline Marine Mammals).

The displacement of bottlenose dolphin under Scenario F is approximately twice that of either of the three projects (Telford, Stevenson and MacColl) or BOWL being built out separately (Scenario D). Figure 4.4.16 in Chapter 4.4: Baseline Marine Mammals provides predicted bottlenose dolphin distribution within the Moray Firth. The construction of the BOWL project is predicted to displace a proportion (17%) of the bottlenose dolphin of the northern coastal waters of the Firth (see Technical Appendix 7.3 F for noise contours), while the construction of the Project is predicted to displace a similar proportion that utilise the southern region of the Firth see Technical Appendix 7.3 F for noise contours) while piling is in operation. For the purposes of this impact assessment, the potential displacement of bottlenose dolphin from the southern regions of the Moray Firth has been considered as worst case.

The population modelling above indicates that while there will clearly be medium term significant impacts to the harbour seal (high magnitude, medium duration), these impacts at a population scale do not extend to long term impacts of population size. Thus the overall impact is considered to be of **low magnitude** (predicted population size within 10% of that predicted as a baseline if population parameters to not change within the Moray Firth) and so **minor significance** for harbour seals.

As with the piling activities within the MORL sites described in Section 4 above, predicted displacement for bottlenose dolphin is not expected from key foraging locations within the Moray Firth SAC, but there is the potential for partial displacement within the commuting corridors and associated foraging areas between the Inner Moray Firth and Forth of Tay/Aberdeen. From this perspective, the temporal pattern of piling is important and considerations of windows within the piling regime are required. MORL Rochdale Envelope calculations estimate that the temporal pattern of piling if one vessel were to be used over a five year duration would be highly intermittent, with a total piling time of 15% of the total construction phase (wind farms and OfTI). As weather and build condition for both the MORL and BOWL sites are likely to be similar, Scenario D would represent an extension of the disturbance duration. A 15% piling time throughout a year would effectively enable passage from one feeding area to another if there is an impact upon this commuting during piling. If the number of piling vessels were greater than one, the number and duration of these windows may reduce, although weather considerations would still be likely to provide some longer periods between piling. Such a decrease in the duration of pile-free windows would be compensated by a reduced overall construction phase if multiple vessels were utilised over an overall shorter construction phase. The overall, long term impact upon the bottlenose dolphin is considered to be of **low magnitude** (predicted population size within 10% of that predicted as a baseline if population parameters to not change within the Moray Firth) and so **minor significance**.

A similar qualitative modelling approach has been taken to the medium and long term impact assessment for grey seals, harbour porpoises and minke whales, although population modelling has not been undertaken for these species. Many of the grey seals observed within the Moray Firth are believed to have originated from haul-out sites outside of the Moray Firth (see Technical Appendix 4.4 A: Baseline marine mammals). While the impacts of behavioural displacement on grey seals within the Moray Firth are considered to be of **major significance** in the **medium term**, given that grey seals do not appear to be tied to specific breeding or feeding grounds within the Moray Firth it is suggested that the long term impact on this species at the population level will be of **minor significance**.

Both harbour porpoise and minke whales exhibit widespread distributions and do not appear to be tied to specific feeding or breeding grounds. The impacts from piling within the wind farm sites on individuals within the Moray Firth are considered of **major significance** in the **medium term.** However, given the generalised distribution and relative abundance of both species, the long term impacts at the population level will be of **minor significance**.

7.1.2 Collision risk

The assessment discussed in Section 7.1.2 is further expanded to include vessel use at the neighbouring BOWL development site and the proposed SHETL hub and cable.

SHETL are proposing to install subsea cable between Shetland and Portgordon on the southern Moray coast. Cable burial along the 320 km route will be achieved through either jetting or ploughing techniques to a target depth of 1 m. Subsea cable installation is timetabled for 2013 and will therefore not coincide with either the MORL or BOWL construction timetables and is therefore not considered further in this assessment. Should the project be delayed, it is not envisioned that the number of vessels required to install the subsea cable will be sufficient to increase effects predicted within the assessment.

The BOWL site is predicted to take two years to construct if using two piling vessels (2014 and 2015) or three years with a single piling vessel (2014 to 2016 inclusive). The first option would result in construction at the BOWL site being completed prior to construction beginning at the MORL site, while the second option would involve an overlap in construction activities for a period of one year in case of no delays in BOWL's programme. In either case, it is considered that the overall increase in vessel use within the Moray Firth associated with the BOWL site will be considerably less than that associated with the MORL site if piling with six piling vessels simultaneously over two years (given a target capacity of 1 GW for BOWL and 1.5 GW for the three MORL sites).

The worst case scenario for the proposed MORL developments (Telford, MacColl and Stevenson) discussed in Section 7.1.2 involves a two year construction period equating to a predicted 711 extra vessel transits within the Moray Firth per year or two trips per day. For the purpose of this assessment, it is assumed that vessel transits associated with the BOWL development will be roughly one third of that predicted for the MORL site.

The SNH report previously discussed (Lusseau *et al*., 2011) predicts that an increase in vessel use of 800 vessels from two separate locations within the Moray Firth is unlikely to result in population effects that could lead to a decline in population size, based on the small increase in exposure predicted combined with the fact that commercial traffic is predictable and less likely to have an effect on bottlenose dolphins than unpredictable recreational vessels.

As previously discussed, the coastal nature of the resident bottlenose dolphin population suggests that they would have the greatest chance of coming into contact with vessels associated with the construction of an offshore wind farm; especially if the vessels transit through areas known to be frequented by the dolphins (as would be the case if a facility were developed at Nigg). The general distribution across the Moray Firth of the other marine mammal species under investigation in this assessment suggests they have less potential to come into contact with vessels associated with construction. In addition, the vessels under consideration would be slow moving along a predictable path, making it easier for marine mammals to avoid the shipping lane if warranted.

Should no overlap occur in construction activities between the MORL and BOWL developments, given the level of vessel traffic already within the Moray Firth to which marine mammals are accustomed to, it is considered that marine mammals will become accustomed to the new vessel traffic and any impacts will be of **low magnitude** for a **medium duration,** and **minor significance**.

Should construction activities at the MORL and BOWL development areas overlap, based on the results presented by the SNH, the cumulative impact of increased vessel traffic on grey seals, harbour seals, harbour porpoise and minke whale is considered to be **of low magnitude** for a **medium duration** and thus have a **minor significance**. Likewise, based on the results presented by the SNH modelling impacts of increased vessel usage on bottlenose dolphins, the cumulative impact of increased vessel traffic on the resident population of bottlenose dolphins is also considered to be **low magnitude** for **medium duration** and **minor significance**.

7.1.3 Reduction in prey due to construction activities (noise)

This secondary impact on marine mammals is discussed fully in Chapter 14.2: Fish and Shellfish Ecology. This investigates the cumulative impacts of noise produced from piling during the installation of the three MORL developments (Telford, MacColl and Stevenson) and the BOWL site.

Noise modelling was conducted to predict impact ranges from piling noise produced at the MORL and BOWL sites simultaneously on key fish species (see Sections 14.2: Fish and shellfish ecology and 3.6: Underwater noise). Impact ranges were found to be similar to those derived from the worst case scenarios for the Telford, Stevenson and MacColl sites alone suggesting limited cumulative effects with the BOWL development.

The cumulative impacts from noise during construction on potential marine mammal prey species are therefore considered to be of **low magnitude, medium duration** and therefore of **minor significance.**

7.1.4 Changes in prey availability due to infrastructure (habitat loss)

This secondary impact on marine mammals is discussed fully in Chapter 14.2: Fish and Shellfish Ecology. This investigates the cumulative impacts from habitat loss resulting from the installation of the three MORL developments (Telford, MacColl and Stevenson), BOWL, the WDA and the SHETL hub and cable.

It is predicted that the installation of these additional developments will result in an incremental loss of habitat as a result of successive foundation placement however this loss of seabed is expected to be small in relation to the distribution range of fish species in the area. The cumulative impacts on potential marine mammal prey species are therefore considered to be of **low magnitude,** over the **long term duration** and therefore of **minor significance**.

7.1.5 Oil and Gas activity

2D seismic surveys were undertaken across two distinct sites within the Moray Firth by PA Resources and Caithness Petroleum during the summer of 2011. Although the results of these surveys are not know at this time, MORL will continue to consult with both organisations to understand if/when any further activities or drilling operations are scheduled.

7.1.6 Low flying aircraft

As part of the scoping process, the Whale & Dolphin Conservation Society (WDCS) raised the issue of whether it was necessary to consider MoD aviation activity as a potential cumulative impact with underwater noise impacts from construction activities (Table 4.4.1, ES Chapter 4.4).

Airborne sounds from aircraft are of potential significance to marine mammals that haul out on land (seals), and may in some circumstances be relevant to any animals at the water surface. However, the complex process of air to water transmission is likely to affect the sound characteristics and limit the levels reaching any animals underwater. For example, when the angle between the aircraft and the underwater marine mammal is greater than 13° from vertical, the majority of the sound is reflected off the water surface and does not penetrate into the water column (Richardson *et al*. 1995). Underwater sounds are therefore greatest for marine mammals close to the surface when the aircraft is directly overhead. Levels decrease with increasing aircraft altitude and vertical angle, and increasing marine mammal depth.

Nevertheless, some aircraft can produce relatively high sound levels at certain times; jet engines during take-off in particular can produce relatively high sound levels. For example, Richardson (1995) has reported received sound levels at the water surface for jets 300 m overhead (during take-off or using afterburners) which peaked at approximately 125-135 dB re 1µPa for frequencies between 100 and 1,000 Hz. However, when viewed in the context of other man-made and natural sources of noise in the marine environment, these levels are relatively low and transient in nature.

Overall, underwater noise from passing aircraft is generally brief in duration (especially when compared to the duration of audibility in the air). Furthermore, unless the aircraft is directly overhead (± 13° from vertical), the sound it produces is likely to be inaudible or weakly audible to a marine mammal underwater (Richardson et al. 1995). Given these are relatively short lived events with relatively low sound levels; it appears unlikely that they would lead to significant adverse effects on marine mammals, either in isolation or in combination with other activities described here. Therefore, potential effects of low flying aircraft on marine mammals are assessed as **not significant.**

In addition, the potential cumulative effects from MoD activities have now been scoped out of the assessment as the MoD danger area that was partially located within the Project area has been removed (please seen Chapter 8.3 for more details).

7.2 Cumulative impacts outside the Moray Firth

A number of renewable developments outside of the Moray Firth are considered in conjunction with the proposed MORL (and BOWL) developments (see Table 7.1).

There are currently three offshore wind proposals off the Firths of Forth and Tay:

- Mainstream are proposing an up to 420 MW scheme at Neart na Gaoithe which is scheduled to begin construction in 2014.
- SeaGreen (a consortia between SSE and Fluor) are proposing up to three phases of development within the Round 3 Zone outside the 12 nmile boundary. The consortia are currently preparing an impact assessment for Phase 1 for up to 1,000MW, within the northern region of the Zone. This phase is scheduled to begin construction in 2015.
- Repsol and EDPR are proposing an up to 1,190 MW at Inch Cape which is scheduled to begin construction in 2016.

If consented, development within this region could span from 2014 to 2018, and beyond if SeaGreen consent Phases 2 and 3 of the Round 3 Zone. While MORL do not have details of construction methodologies for these three developments, it is understood that some degree of foundation piling will be included within the Rochdale Envelopes. For the purposes of this study, it has been assumed that the noise associated with foundation installation within the region could displace marine mammals from these areas.

A wind demonstrator project is also proposed in Aberdeen Bay. If consented, the European Offshore Wind Deployment Centre (EOWDC) will comprise of 11 turbines, each with an output of between 4 and 10 MW (max 100 MW for site), positioned approximately 2.4 km from the shore. There are currently five options of turbine foundation type: monopole, gravity base, tripod, steel jacket and suction caisson. For the purposes of this study, it has been assumed that the noise associated with foundation installation within the region could displace temporarily marine mammals from area. The indicative construction program is based on two construction periods: 4 turbines to be installed in 2013 with the remaining turbines installed in 2014.

Eleven wave and tidal power projects have been awarded lease options by the Crown Estate within the Pentland Firth and Orkney waters strategic area. The developments are not far enough through the design and licensing process to be able to offer details on installation methodologies, however it is likely that jack-up barges, drilling, DP vessels and potentially some piling may be required. Each project has its' own timeline for works agreed with The Crown Estate, however an approximate summary of proposed timescales is for small scale work to commence in 2013-2015 with large scale work due to commence in 2016.

Table 7.8 below presents a visual representation of the proposed construction periods for the developments included in this cumulative assessment, based on the information available at the time of production.

Table 7.8: Representation of possible the construction programmes for developments under consideration in the cumulative impact assessment. The dark grey squares illustrate the minimum possible construction period with the blue squares the maximum depending on construction timetables.

	2012	2013	2014	2015	2016	2017	2018	2019	2020
MORL									
BOWL									
SHETL									
F & T									
EOWDC									
W & T									

It should be noted that the limited project information available to date prevents the following cumulative impact assessment to follow the standard methodology described previously. The impact assessment therefore forms more of a discussion, based on reviews of current knowledge (including information from monitoring studies carried out in operational wind farms) and evidence presented within this report.

The primary focus of this assessment is related to increased anthropogenic noise from piling activities.

Construction activities for the proposed demonstrator site in Aberdeen Bay (EOWDC) are scheduled for the summer months of 2013/2014, and will therefore be completed before construction begins within the three MORL developments under discussion (Telford, Stevenson and MacColl).

In addition, the short construction period predicted for the Aberdeen development suggests that cumulative impacts on marine mammals between this and the MORL developments will be minimal. As a result, the Aberdeen development is not discussed in detail in this assessment and the primary focus will be cumulative impacts between construction activities within the Moray Firth (MORL and BOWL) and the Forth and Tay projects.

Cumulative impacts with wave and tidal projects proposed in Pentland Firth and Orkney Waters are not predicted to have direct impact on marine mammals within the Moray Firth but may have indirect impacts in the unlikely event that animals are displaced from the Moray Firth and relocate to the waters around Orkney. This unexpected relocation would place them at an increased risk of collision from underwater turbines.

Connectivity with areas outside of the Moray Firth

Substantial grey seal breeding colonies can be found in Orkney, the Isle of May and the Farne Islands, with a combined pup production of over 26,000 estimated for 2010 (SCOS, 2011). Tagging studies have shown that individuals from all of these sites visit the Moray Firth, with such trips often lasting several days and thought to be associated with foraging (see ES Chapter 4.4: Baseline Marine Mammals and associated Technical Appendix).

Harbour seal movements are more localised than grey seal movements (Technical Appendix4.4 A: Baseline Marine Mammals) with little movement between widely separated haul-out sites. For example, tagging studies on harbour seals from within the Moray Firth demonstrate that they forage within the Firth and do not travel extensively to other haul-out sites (see ES Chapter 4.4 and associated Technical Appendix). It has been estimated that 79% of the UK population of harbour seals can be found around Scotland with many of the local populations in decline. For example, compared to the mid 1990's, population estimates in Shetland have declined by 50%, in Orkney by 68% and in the Firth of Tay by 85%.

A portion of the bottlenose dolphin population found within the Moray Firth travel throughout the coastal regions of the east coast of Scotland, spend periods of time at several locations along the coast including Aberdeen harbour and the Tay estuary.

Current understanding of harbour porpoise and minke whale behaviour suggests their distribution is widespread and they are not restricted to specific areas or habitat types; nor have discrete populations been identified (see ES Chapter 4.4 and associated Technical Appendix).

Harbour seals

As discussed in Chapter 4.4: Marine Mammals Baseline, results from harbour seals tagged at Moray Firth haul-out sites demonstrate that they remain in the area when foraging. It is therefore unlikely that animals from this population will be directly affected by piling noise occurring at developments near the Forth and Tay or in the Pentland Firth and Orkney waters.

The levels of displacement predicted by the most precautionary models used in this ES suggest that up to 61 - 75% of harbour seals may be displaced from regions of the Moray Firth affected by piling activities. The duration of this displacement is unknown, but it is expected to be temporary by scientific experts, and forthcoming data from DECC funded studies in the Wash can be used to test these hypotheses. Nevertheless, in the interim the most conservative assumption that animals are excluded for the whole year has been used in the modelling undertaken to inform this impact assessment and has identified no long term impact on the viability of this harbour seal population.

Displaced seals are likely to use alternative foraging areas within the Moray Firth where there are lower levels of disturbance. As seen during periods of natural changes in prey availability, these changes may also lead to temporary changes in the use of different Moray Firth haul-out sites (Thompson et al. 1996). Harbour seals are not expected to be displaced to areas outside of the Moray Firth, and so would not suffer cumulative impact with projects occurring within the Firths of Forth and Tay or Pentland Firth and Orkney waters.

Grey seals

Grey seals will travel over much larger areas than harbour seals, with tracking studies showing that many of the grey seals tracked within the Moray Firth originated from haul-out sites further afield. A number of the seals tracked within the Moray Firth were tagged on the Isle of May, confirming connectivity between the Moray Firth and the Firths of Forth and Tay.

Construction activities for the wind farms of the Firths of Tay and Forth are predicted to coincide with those of the Moray Firth over the period of 2014-2020. Precautionary modelling conducted for this ES predicts that between 32 - 52% of grey seals currently using the Moray Firth may be displaced from the area during construction, depending on the construction scenario. Tracking studies demonstrate that should foraging areas close to piling events become less preferable to grey seals, they are capable of travelling to alternative areas. The large foraging range of this species will ensure that feeding areas outside of the noise influence from construction of the Firth of Forth and Tay, and Pentland Firth and Orkney waters should the construction phases of these projects coincide, is likely.

Harbour porpoise

Using the most conservative assumptions, between 65 - 84% of harbour porpoise within the Moray Firth may be displaced during the piling activities within the Moray Firth, depending on the construction scenario. Harbour porpoise exhibit widespread distributions and are not tied to specific feeding or breeding grounds within the Moray Firth or elsewhere in the North Sea or North Atlantic. A population structure workshop held in 2007 under the aegis of the Agreement on the Conservation of Small Cetaceans of the Baltic, North-East Atlantic, Irish and North Seas (ASCOBANS) and the Helsinki Commission (HELCOM) concluded that there was some population structure within the North Sea, but the evidence was insufficient to define boundaries between any (sub-) populations at the time (ASCOBANS, 2009). Consequently, for the purposes of conservation, harbour porpoise in the North Sea are considered to represent a single population.

Relatively large numbers of harbour porpoise may be displaced from the Moray Firth and, although the details are not presently available, it can be assumed that significant numbers may be displaced from the Forth and Tay and Pentland Firth and Orkney waters areas due to piling associated with developments. Although the local effects from piling will be significant on this species in the areas surrounding specific construction activities, the generalised distribution of this species suggests that the cumulative effects across such a wide area will be relatively low and that alternative foraging areas in the North Sea for harbour porpoises are likely to be available.

Bottlenose dolphins

The north east of Scotland population of bottlenose dolphins is known to range over a wide area of coast from the Moray Firth down to the Forth and Tay and beyond (Technical Appendix 4.4 A: Baseline Marine Mammals). Sightings of bottlenose dolphins tend to be close to the coast, with the majority occurring in waters of less than 25 m deep (Hastie *et al*., 2003; Canning, 2007; Robinson *et al*., 2007).

The extent to which Moray Firth SAC bottlenose dolphins are expected to be directly affected by piling noise in the Forth and Tay area is not currently known. The most precautionary models discussed within this document predict that between 16 - 42% of the population could be disturbed within the Moray Firth as a result of piling noise. This value falls to between 11 - 34% using the model of best fit. Predicted noise levels within those parts of the Moray Firth frequented by bottlenose dolphins are not expected to be sufficient to exclude animals from these areas. Nevertheless, the coastal nature of this population suggests that should piling lead to some individuals moving outside the Moray Firth, they could be further exposed to piling activities along the eastern coast, in particular in the Forth and Tay region. Piling activities at Aberdeen are predicted to be short in duration and completed prior to construction activities beginning at either the three proposed wind farm sites or in the Forth and Tay region; although there may be some overlap with the BOWL development within the Moray Firth. Details of levels of displacement likely to occur as a result of piling in the Forth and Tay area were not available to MORL at the time of publication (of this ES).

Minke whale

Using the precautionary fit, up to 15% of minke whales within the Moray Firth could be displaced during the piling activities. As with harbour porpoise, minke whales exhibit generalised distributions throughout the North Sea or North Atlantic. It is unclear whether minke whales in UK waters move slightly offshore during the winter months or migrate further afield. If population differentiation between North Atlantic minke whales from different regions exists, it seems present only at low levels (Árnason & Spilliaert, 1991; Daníelsdóttir *et al*., 1992; Bakke *et al*., 1996; Martinez & Pastene, 1999; Andersen *et al*., 2003; Anderwald *et al*., 2011). Sightings within the Moray Firth appear are most common between April and September, as has been reported for other areas (see Technical Appendix 4.4 A: Baseline Marine Mammals).

As discussed, impact assessments for the Forth and Tay offshore wind projects (Neart na Gaoithe, Firth of Forth and Inch Cape) are not presently available. Potential effects from development of wave and tidal projects within the Pentland Firth and Ornkey waters as also now know. Although the local effects from piling may be significant on this species in the areas surrounding specific construction activities, the generalised distribution of this species suggests that the cumulative effects across such a wide area of coastline will be minimal and that alternative areas in the northeast Atlantic for minke whales to forage are likely to be extensive.

8. Mitigation and Management Measures

The information below summarises potential mitigation and management measures which it is proposed be applied during the different stages of the proposed developments.

8.1 Construction phase

The primary impact on marine mammals during the construction phase of the proposed developments (Stevenson, Telford and MacColl) is predicted to be from piling noise. MORL is working with The Crown Estate and other developers to investigate and develop best practice for mitigation measures that may be implemented to reduce either the level of noise at the source or noise propagation. These investigations have shown that measures to attenuate underwater noise are at the concept design or early prototype testing stage, and thus not currently commercially viable.

Existing Joint Nature Conservation Committee (JNCC) guidelines require the presence of a marine mammal observer prior to piling commencing and the instigation of a "soft start" procedure once piling starts. Typically this involves a 30 minute visual watch being conducted prior to all piling operations along with a 30 minute acoustic survey. If a marine mammal is observed (visually or acoustically) within 500 m of the piling vessel during this period, piling is delayed until the animal has moved away from the area (outside of the 500 m buffer) or has not been sighted for 20 minutes.

Recent developments in passive acoustic monitoring technology promises to improve the potential to detect cetaceans in low light or poor weather conditions. Similarly, more effective acoustic deterrents are being developed to exclude seals from potential impact areas. It is anticipated that these developments may lead to more effective mitigation procedures within the life-time of this project. The use of alternative approaches will be investigated prior to construction commencing and their use decided upon after consultation with regulatory bodies.

Given the small radii predicted to cause physical injury to marine mammals, mitigation will focus on ensuring that marine mammals are outside a 500 m buffer zone to reduce such impacts. Once piling begins, the power will be ramped up in stages thus giving the majority of marine mammals outside of this area the opportunity to move away from the area prior to the piling hammer reaching full power (and maximum noise generation).

The soft start procedure will involve the ramping up of power over a 20 minute period until the hammer reached optimal force. This procedure has already been factored into the noise propagation models discussed in Chapter 7.2 and therefore residual impacts have already been included in the impact assessment.

The risk to marine mammals of collision with construction vessels is predicted to be negligible and of low significance. Although mitigation is not considered a necessity, the designation of a navigational route for construction vessel traffic will aid marine mammals to predict vessel movement and reduce potential impacts.

8.2 Operational phase

The risk to marine mammals of collision with operational and maintenance vessels is predicted to be negligible and of low significance. Although mitigation is not considered a necessity, the designation of a navigational route for construction vessel traffic will aid marine mammals to predict vessel movement and reduce potential impacts.

8.3 Decommissioning phase

The decommissioning plan has not yet been finalised and will be dependent on the choice of turbine structure, therefore detailed mitigation is not possible at this stage. The most likely scenario would involve the use of cutting equipment and is predicted to be of low to medium magnitude to marine mammals. Once the decommissioning program has been decided upon, a review of mitigation requirements will be undertaken and instigated as required based on the best available procedures at the time.

9. References

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